# Annals of Warsaw University of Life Sciences: Forestry and Wood Technology

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Influence of the environmental pollution degree on the chemical composition of wood and bark of Scots pine (Pinus sylvestris L.)

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Abstract: Influence of the environmental pollution degree on the chemical composition of wood and bark of Scots pine (Pinus sylvestris L.). Nine cca. 80-year old stems of Scots pine (Pinus sylvestris L.) were analyzed. They were gained from pine stems gained from the I<sup>st</sup>, II<sup>nd</sup> and III<sup>rd</sup> zone of industrial damages (tree degradation). Disks of about 300 mm thick were cut from butt-end section, half height and top part of a stem. Samples from following zones were collected: sapwood, heartwood adjacent sapwood and heartwood. Measurements of annual rings width and late wood participation had been performed before samples for chemical analysis were collected. The results prove that the environmental pollution influence these quantities. It also impacts on the extractives content (decrease in bark from butt-end section), content (increase in bark) and distribution of 1% NaOH soluble substances (changes both on cross- and longitudinal sections), and lignin distribution on stems cross-section.

Keywords: pine, sapwood, heartwood, cellulose, lignin, 1% NaOH soluble substances

INTRODUCTION

Changes of content and distribution of extractives and mineral substances may be caused by environmental pollution. Also content and distribution of wood structural substances on the cross- and longitudinal-section is dependent on environmental pollution degree (Krutul et al. 2006, 2010, 2011). As changes caused by environmental pollution are connected with reduction of annual rings width and increase of late wood participation (in relation to samples from unpolluted environment), most of studies found in literature concern this issue (Watmough and Hutchinson 2002, Oleksyn et al. 1993).

According to former papers of Krutul et al. (2006), the action of heat and power plant on chemical composition of pine wood and bark (Pinus sylvestris L.), collected from the distance of 1 and 21 km from pollution source, influences on lignin content (increase) as well as the distribution of 1% NaOH soluble substances on the cross-section.

Other studies of Krutul et al. (2011) describes the impact of heat and power plant on the chemical composition of birch (Betula pendula Roth.) wood and bark. Samples were collected 21 km from pollution source which causes changes of extractives distribution on the cross-section. Distribution of 1% NaOH soluble substances on the longitudinal section is also changed.

Nitrogen Industrial Plant “Kędzierzyn” has performed production of ammonia, nitric acid and nitrogenous fertilizers since 1954. Phthalic acid anhydride, waxes and fatty acids were additional products. Heat and power station was also built in the area. Since the beginning of 80’s condition of the environment has begun to improve because of eco-policy.

The aim of this paper is the determination of the influence of Nitrogen Industrial Plant on the chemical composition of pine (Pinus sylvestris L.) wood and bark on the stem cross-section at different heights. Stems obtained from environments with different pollution degree were examined.
MATERIALS AND METHODS

Analyzed stems of Scots pine (Pinus sylvestris L.) were collected from Vth Silesian region in December. Three cca. 80-year old trees were cut from each of environments – one tree was cut from the Ist zone of industrial damages (weak pollution, samples collected in the distance of 25 km from the industrial plant) one from the IInd zone (strong pollution, samples collected in the distance of 15 km from the industrial plant) and one tree from the IIIrd zone (very strong pollution, samples collected in the distance of 1 km from the industrial plant). Three 300 mm thick disks were cut from each analyzed stem (from butt-end section, half height and top part). Following zones were distinguished on disks cross-section: perimeter adjacent, sapwood, heartwood adjacent sapwood and heartwood. Each zone contained 10 annual increments. Samples for analysis were collected using drill on the whole disk perimeter. Obtained chips were fractioned on sieves. Fraction passing 1.2 mm and remaining on 0.49 mm mesh sieve was taken for analysis.

Extractives were analyzed in Soxhlet apparatus using ethanol-toluene (1:1) mixture, cellulose – with Kürschner-Hoffer method, lignin – according to PN-74/P50092 (Krutul 2002). Additionally, 1% NaOH soluble substances were examined. Three parallel measurements were performed for each analyzed zone. Results were acknowledged as correct when the difference between results was lower than 0.05. Average values from three stems collected in each environment were compared. Each disk was also analyzed to determine annual increments width and late wood share, according to PN-D-04110. Annual increments width was analyzed on four cardinal point on the compass on each disk and average values from each environment were calculated.

RESULTS AND DISCUSSION

Mean values of annual increments width and late wood share dependent on environmental pollution degree are presented in the Tab. 1. Values of annual increments width for cross-sections of stems from environments characterized with weak and strong pollution in sapwood are cca. 25% higher in relation to samples from environment, where pollution is very strong.

<table>
<thead>
<tr>
<th>height</th>
<th>zone</th>
<th>Ist degradation degree</th>
<th>IIInd degradation degree</th>
<th>IIIrd degradation degree</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td></td>
<td>ring width/mm</td>
<td>latewood part/%</td>
<td>ring width/mm</td>
</tr>
<tr>
<td>butt-end</td>
<td>sapwood</td>
<td>1.6</td>
<td>31.6</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>h. a. s.*</td>
<td>1.6</td>
<td>41.8</td>
<td>1.1</td>
</tr>
<tr>
<td>middle</td>
<td>heartwood</td>
<td>3.8</td>
<td>37.6</td>
<td>3.7</td>
</tr>
<tr>
<td></td>
<td>h. a. s.</td>
<td>0.9</td>
<td>45.3</td>
<td>0.9</td>
</tr>
<tr>
<td>top</td>
<td>sapwood</td>
<td>1.6</td>
<td>31.1</td>
<td>1.6</td>
</tr>
<tr>
<td></td>
<td>h. a. s.</td>
<td>3.1</td>
<td>32.1</td>
<td>2.9</td>
</tr>
<tr>
<td></td>
<td>heartwood</td>
<td>2.7</td>
<td>31.2</td>
<td>2.2</td>
</tr>
<tr>
<td></td>
<td>h. a. s.</td>
<td>1.6</td>
<td>24.9</td>
<td>1.6</td>
</tr>
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*heartwood adjacent sapwood

Annual rings in heartwood adjacent sapwood are wider in stems gained from weak polluted environment in comparison to disks obtained from the environment with strong and very strong pollution. Apart from the pollution degree, annual increments width is similar in butt-end section of analyzed stems. Very strong pollution causes cca. 60% decrease in annual rings width in the top part of the stem (comparing to disks with Ist and IInd degradation degree).
As it arises from presented results, environmental pollution influences annual increments width. These results are compatible with Krutul’s (1994), who examined annual rings of 110 year old pine stem on the height of 2, 6 and 10 m, gained from unpolluted area. Annual increments on the analyzed cross sections are the narrowest in sapwood and sapwood adjacent heartwood zones.

The share of late wood in stems collected from the environment acknowledged as very strongly polluted, in sapwood is 20% higher than in heartwood. In stems with Ist and IInd degradation degree (weak and strong pollution) the share of late wood in heartwood adjacent sapwood is higher in relation to sapwood and heartwood zones, both in butt-end and middle stem section (Tab. 1).

As it arises from the data presented in the Fig. 1, extractives content decreases in the direction from pith to stem perimeter, regardless of environmental pollution and stem section. Heartwood zone contains more extractives in relation to heartwood adjacent sapwood and sapwood. According to presented data, environmental pollution does not influence the extractives content on analyzed cross-sections. Extractives content in bark from stems with IIIrd degradation degree is cca. 20% lower in comparison to material with Ist degradation degree (Fig. 1).

![Figure 1. Extractives content in wood and bark of analyzed Scots pine](image)

Krutul et al. (2006) stated that extractives content in pine stems (*Pinus sylvestris* L.) collected from the areas 1km and 2km far away from “Kozienice” heat and power plant is lower in relation to stems gained from unpolluted environment.

According to the presented data, environmental pollution causes the decrease of extractives content in pine bark, regardless of substances and emitters which are the pollution source.

Cellulose content increases in the direction from pith to the stem perimeter and does not depend on environmental pollution and stem section. Cellulose content is more dependent on the share of late wood than on the environmental pollution, as it may be observed in the
Fig. 2. As it was stated in the paper of Krutul (1994), the dependence between share of late wood and cellulose content on the cross-section of pine wood (*Pinus sylvestris* L.) collected from unpolluted environment is linear. In the sapwood from top section of the stem cellulose content is lower in comparison to sapwood from other stem sections, what is compatible with data presented by Krutul (1994). Cellulose content in bark is cca. 50% lower in relation to wood, regardless of environmental pollution. Obtained cellulose content in bark of pine is cca. 30% lower in comparison to data presented by Fengel and Wegener (1984) and cca. 15 higher in relation to data collected by Krzysik (1984).

![Figure 2. Cellulose content in wood and bark of analyzed Scots pine](image)

Summarizing, environmental pollution did not influence the cellulose content and distribution on the cross- and longitudinal section of analyzed stems. The character of cellulose content changes in analyzed stems on the cross-section is similar with data obtained by Krutul (1986, 1988), as well as with this presented by Uprichard (1971) and Harwood (1971), who stated that cellulose content on cross sections of *Pinus radiata* wood increases in the direction from pith to stem perimeter.

As it arises from the data presented in the Fig. 3, 1% NaOH soluble substances content in heartwood from stems with I*st* degradation degree is 5-7% higher in relation to sapwood zone. This difference in stems with II*rd* degradation degree (very strong pollution) is more significant (30-35%), while in stems with I*нд* degradation degree there was no difference observed regardless of stem height.

According to Krutul et al. (2006), on the cross sections of pine stems (*Pinus sylvestris* L.) gained from unpolluted area 1% NaOH soluble substances content decreases in direction from pith to stem perimeter. Content of these substances in stems collected 21 km far away from heat and power plant in sapwood is cca. 25% higher in comparison to heartwood in butt-end as well as in middle and top section.
Figure 3. 1% NaOH soluble substances content in wood and bark of analyzed Scots pine

Presented data shows that 1% NaOH soluble substances content, both on cross- and longitudinal section, is influenced by environmental pollution, regardless of substance and emitter causing pollution.

Changes in 1% NaOH soluble substances content caused by nitrogen industrial plant are the most significant in bark from stems with Ist and IIrd degradation degree. Content of these substances is cca. 35% higher in relation to bark gained from the distance of 1 km from heat and power plant and cca. 20% higher in comparison to bark from stem collected 21 km from the emitter. Bark from stems with IIrd degradation degree contains respectively 25 and 10% more of 1% NaOH soluble substances (Krutul et al. 2006).

Fengel and Wegener (1984) stated that bark of pine contains 22.1% 1% NaOH soluble substances.

Presented data proves that nitrogen industrial plant “Kędzierzyn” increases 1% NaOH soluble substances content in butt-end section, regardless of degradation degree.

Fig. 4 presents lignin content in analyzed stems. In stems with Ist degradation degree it is lower in comparison to stems with IInd and IIIrd degradation degree, regardless of stem section. In all analyzed stems heartwood contains more lignin than sapwood, what is similar to data presented by Krutul (1998) and Krutul et al. (2006). According to Krutul et al. (2006), heat and power plant causes the increase of lignin content in stems of pine wood collected 1 and 21 km from the emitter, in relation to wood from unpolluted area.

Bark from stems with Ist degradation degree contains cca. 6.5% more lignin than wood. This difference raises to 8 and 20%, respectively for stems with IInd and IIIrd degradation degree (Fig. 4).

According to Fengel and Wegener (1984), lignin content in pine bark equals 39%, while Prosiński (1984) determined lignin content of 43%. Lignin content in bark from stems collected 1 and 21 km far from the heat and power plant is respectively 46.5 and 48.3% (Krutul et al. 2006). Then it may be stated that nitrogen industrial plant decreased the lignin content in pine bark and influenced its distribution on cross-sections.
CONCLUSIONS
On the base of presented results following conclusions can be drawn:

- Environmental pollution changes annual increments width in Scots pine wood, as well as the share of late wood.
- Environmental pollution does not influence the content and distribution of extractives, but decreases its content in bark of butt-end section.
- Cellulose content in analyzed pine stems is more dependent on late wood share than environmental pollution. Regardless of environmental pollution degree, cellulose content in bark is cca. 50% lower in relation to wood.
- Environmental pollution influences the content and distribution of 1% NaOH soluble substances, both on cross- and longitudinal section. Also its content in bark is decreased.
- Environmental pollution influences lignin distribution on the stem cross-section and decreases its content in bark.

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**Streszczenie.** Wpływ stopnia skażenia środowiska na skład chemiczny drewna i kory sosny zwyczajnej (Pinus sylvestris L.). Badania udziału drewna późnego, substancji ekstrakcyjnych, celulozy, substancji rozpuszczalnych w 1% NaOH oraz ligniny przeprowadzono w około 80-letnich pniach sosny zwyczajnej (Pinus sylvestris L.) pozyskanych z V-tej Krainy Śląskiej z trzech obszarów uszkodzeń drzewostanów przez szkodliwe emisje przemysłowe: I–obszar−uszkodzenia słabe, II–obszar-uszkodzenia silne, III–obszar-uszkodzenia bardzo silne. Z każdego drzewa pobrano po 3 krążki o grubości około 300 mm z części odziomkowej, w połowie długości i z części wierzchołkowej strzały. Na przekroju poprzecznym wyróżniono strefę bielu, strefę twardzieli graniczącą ze strefą bielu i strefę twardzieli, a każda ze stref zawierała po 10 przyrostów rocznych.

Na podstawie uzyskanych wyników badań stwierdzono, że skażenie środowiska wpływa na szerokość przyrostów rocznych i zwiększa udział drewna późnego w drewnie strefy bielu i w drewnie strefy twardzieli graniczącej ze strefą bielu w części odziomkowej pni.
Badane skażenia środowiska nie wywarło wpływu na zawartość i rozmieszczenie substancji ekstrakcyjnych na przekrojach poprzecznych pni, natomiast wywarło wpływ na zmniejszenie ich zawartości w korze w części odziomkowej pni. Zawartość celulozy jest związana z udziałem drewna późnego i stąd jej zawartość w drewnie pozyskanym ze środowiska o bardzo silnym stopniu skażenia jest większa w stosunku do drewna pozyskanego ze środowiska o silnym i słabym stopniu skażenia.

Natomiast skażenie środowiska wywarło wpływ na rozmieszczenie substancji rozpuszczalnych w 1% NaOH na przekrojach poprzecznych i wzdłuż wysokości pnia sosny zwyczajnej (Pinus sylvestris L.). Również skażenie środowiska wpłynęło na rozmieszczenie ligniny na przekrojach poprzecznych pni i wpłynęło na zmniejszenie jej zawartości w korze.

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Effect of lignin addition on the performance of microbial fuel cell.

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Abstract: Effect of lignin addition on the performance of microbial fuel cell. Lignin was reported to have inhibitory effect on MFC operation. Products of lignin degradation were shown to decrease bacteria viability and efficiency, often leading to bacteria cell death. The aim of the work was to verify lignin addition effect on the performance of MFC. It was observed that after introducing to the reactors 10 g/l of lignin, bacteria from anode biofilm survived and MFC operation was not disturbed when compared with MFC where lignin was not added. The results show no inhibitory effect of lignin addition on biocurrent generation in the investigated conditions.

Keywords: microbial fuel cell, lignin, bacteria inhibition

INTRODUCTION

Microbial fuel cell technologies are promising approach for the production of energy from organic matter. It has been used great variety of substrates in MFC systems, from pure compounds like acetate, simple sugars: glucose, mannitol, xylose to complex mixtures of organic matter like wastewater (Debavov, 2008). MFC systems are also used for wastewater treatment where side effect is current production. This way it is possible to make savings in energy needed for wastewater aeration during its conventional treatment (50% of the electricity used in the treatment plant). As MFC processes are anaerobic it is also possible to reduce bacterial biomass production in comparison to aerobic treatment. Thus, reduced solids production allows for reducing energy and costs of its utilization (Toczyłowska-Mamińska, 2017).

Among lignocellulosic materials, lignin (complex aromatic macromolecule building plant cell walls) is the main source of inhibitory compounds (Dunlop 2011). Products of lignin degradation are known to have negative effect on bacteria in MFC systems and its presence in high content often hinders MFC bacteria metabolism (Ibraheem et al. 2013). Lignin degradation products such as catechol, vanillin, phenolic compounds or ferulic acid are known to decrease fermentation bacteria viability and their efficiency (Mikulaasova et al. 1990). The mechanism of cytotoxicity of inhibitory compounds derived from lignins and other lignocellulosic materials can differ, but the result is similar. For example, phenolic compounds block cell membranes what alters membrane permeability. This leads to membrane disruption, reducing ATP cell levels and impaired protein and nutrient transport. The consequence is high reactive oxygen species (ROS) production damaging cell proteins and enzymes what results in its denaturation and cell death (Zimmermann 1990). Thus, high content of inhibitory compounds in wastewater may lead to bacteria death in MFC system what enable wastewater treatment in such system. The presence and concentration of inhibitory compounds strongly affects wastewater treatment effectiveness in MFC systems.

The aim of the work was investigating the influence of lignin addition on the performance of MFC fed paper recycling wastewater.
MATERIAL AND METHODS

Microbial fuel cell construction and operation. Single chamber MFCs were was constructed as previously described (according to the design described by Logan et al. (2007). The cube-shaped MFC was made from Plexiglas built of the anode and the cathode placed in a by drilling a Plexiglas a cylindrical chamber (4 cm long by 3 cm in diameter, (28 ml of volume). The anode was carbon fiber brush (2 cm long, 2.5 cm diameter) placed in the center of the chamber. The air cathode (7 cm² area) was carbon cloth, and a Pt catalyst. The MFC were fed paper recycling wastewater in 50 mM phosphate buffer solution and after stable power generation lignin was added to the reactors (10g/l). Current and power generation in the MFC were determined by measuring the voltage (U) every 20 min with across fixed external resistance (1000 Ω, unless noted otherwise) with a the self-made Arduino-based automated measuring system connected to with the a computer. Current (I) was calculated from Ohm’s law (I=U/R) and power (P) was calculated as P=IU. Current density and power density were normalized to the projected surface area of the cathode (7 cm²).

RESULTS

The investigations of the influence of lignin addition on MFC performance were made on paper wastewater fed MFCs. According to the previous reports there is no lignin in such type of wastewater (Toczyłowska-Mamińska, 2017). Two identical MFCs types were observed during 80 days of operation. In the first reactor type, biocurrent was produced from paper wastewater without lignin addition (Fig 1a). In the second, lignin was added to the reactor on the 34th day of operation, after obtaining repeatable voltage cycles (Fig. 1b). This way it was possible to observe the differences between reactors operation with and without lignin addition. It can be observed that voltage generated in MFC operating on paper wastewater decreases in time after about 30 days of operation. This effect is observed for MFCs both with and without lignin addition. In case of MFCs where lignin was not added, maximum voltage produced dropped from 180 mV to 70mV during 50 days of operation. In MFC where lignin was added, maximum produced voltage dropped from 250 to 110 mV. Thus, the effect of voltage decrease in time was not connected with lignin addition. It can be also observed that in MFCs with lignin addition maximum voltage stabilized and voltage drop started after ca. 10 days from gaining the maximum value. The obtained results show there is no inhibitory effect of lignin on MFC operation.

SUMMARY

In this work it has been investigated the effect of lignin addition on power production in MFC fed paper recycling wastewater. In contrary to previous reports, the applied lignin additive had no effect on power generated in the system. The observed situation may be caused by microorganisms adaptation to lignin conditions.
Fig. 1. Voltage generation in MFCs operating on paper wastewater: a – no lignin addition; b – with lignin addition. Green line indicates when the lignin was added to the reactor.

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Streszczenie: Wpływ dodatku ligniny na pracę mikrobiologicznego ogniwa paliwowego. Doniesienia literaturowe wskazują na negatywny wpływ ligniny na pracę mikrobiologicznych ogniw paliwowych. Stwierdzono, że produkty degradacji ligniny obniżają żywotność bakterii i ich wydajność, a nawet często powodują śmierć mikroorganizmów pracujących w ogniwie. W niniejszej pracy zbadano wpływ ligniny na produkcję bioelektryczności w mikrobiologicznym ogniwie paliwowym zasilanym ściekiem z produkcji papieru. Po wprowadzeniu do układu 10 g/l ligniny nie zaobserwowano negatywnego jej wpływu na pracę ogniwa, w porównaniu z ogniwa bez dodatku ligniny. Na podstawie badań można stwierdzić brak negatywnego efektu ligniny na produkcję bioelektryczności w zastosowanych warunkach.

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Selected aspects of structural design of timber trusses with punched metal fasteners

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Abstract: Selected aspects of structural design of timber trusses with punched metal fasteners. The paper discusses issues related to calculations of timber trusses when applying Robot Structural Analysis and TrussCon software. The authors draw attention to differences in results obtained when static calculations to identify forces acting in the truss, including flexibility of the nodes, are carried out using traditional methods. The need to apply appropriate standards is also discussed. The paper indicates problems which can arise in static analysis of existing buildings and in designing structural reinforcement (essential, for example, in converted buildings) for structures built in compliance with the old Polish standard which no longer applies.

Keywords: timber structures, nail plates, roof trusses, timber connectors, stability of timber trusses, design of timber structures

INTRODUCTION
Timber roof trusses assembled with nail plates offer a wide range of structural solutions for roofing residential houses, as well as larger buildings, with more complex structures. At the same time, they allow for prefabrication of structural elements. The technology of nail plate joints involves pressing steel plates into the wood with a high load hydraulic press. Spikes (nails) embossed in the plates penetrate the wood and connect elements without having to laboriously nail each of the nodes.

Depending on the required span and the use of a given structure, steel plates of different thickness and nail lengths can be applied. These plates can be made of galvanized or stainless steel. In the case of large-span trusses, which have to be transported as elements and joined on site, one of two possible methods can be applied. The first involves application of nail plates, which are pressed using a mobile press. Alternatively, the plates can be fastened to the wood using nails. The plates are pressed to one of the elements of the truss, and the other element is fastened with nails. In both cases, of course, it is necessary to design an appropriate connection.

Trusses joined with nail plates enable fast construction of roofs, even in the case of complex building structures, as most of the elements are prefabricated and the trusses are relatively light weight. However, it is important to consider the level of complexity of the structure and the characteristics (anisotropic structure) of the timber material when designing the building.

SPECIFYING AND MODELLING DESIGN PARAMETERS
The type of static model selected for calculations is of crucial importance for specifying dimensions of nail plate trusses, but this is something designers often fail to take into account [Neuhaus, 2009]. A nail plate does not create a node in the form of an ideal pinned or fixed joint, but a joint with a certain flexibility. This means that bending moments can occur in truss nodes and these should not be ignored [Kotwica and Nożyński, 2015]. Moreover, according to Chapter 5.4.2 of the Polish standard [PN-EN 1995-1-1], the impact of eccentrics in nodes should also be taken into account, if the actual axes of the truss rods do
not converge as in the ideal model of the truss. Fictional beam elements can be used for modelling eccentric nodes (fig. 1), which reflect the flexibility of joints. Due to the phenomenon of eccentricity, the plates have to be positioned very precisely in the nodes during production. The standard [PN-EN 14250] allows for a maximum 10 mm deviation in the positioning of a joining element when compared to the design specification – irrespective of the direction of deviation.

Software for generating models, static calculations and design, such as Robot Structural Analysis or RmWin, allow for the truss to be introduced as a members system with a pinned or fixed connections. It is possible to model a flexible joint, but this requires introducing flexibility into each node of the truss. At the design stage of a truss, this would require complex calculations of flexibility, which would change if a different type of joint was to be selected, and if its position in the node was changed [Hansson and Ellegaard, 2006]. For this reason, a truss modelled in such a way enables only estimation of member cross-section. Such modelling is not in compliance with standards [PN-EN 1995-1-1], as it excludes bending moments which occur within the nodes. Connections along the chords are also important to mention, as they are often necessary due to limitations arising from the specifications of available materials. For example, a chord modelled using the Robot software is treated as a continuous member, without taking into consideration the need to connect shorter elements. Such connections require appropriate calculations.

Software dedicated for designing this type of structure, such as, e.g., TrussCon or Pamir, can be used to solve problems arising from the specific character of constructing nail plate trusses, in a comprehensive way. They can generate truss models, which account for actual element sections - the actual position of their axes and the fact that they do not converge at a single point – as well as the flexibility of joints, which depends on the type and location of a nail plate. Connectors are selected automatically and the advanced static model changes if a different type of plate is selected. Bending moments in a member is taken into account, as well as redistribution of forces. Fast optimization of the truss members is provided in this way [Tomusiak, 2010]. As established by [Nastulski, 2016], comparative analysis of a truss modelled using the Robot Structural Analysis and TrussCon softwares, indicates that all these issues shape the final results of calculations. For the purpose of the analysis, the same boundary conditions were adopted. Trusses were modelled in a two-dimensional arrangement. The static scheme of a truss modelled using the TrussCon software is presented in fig. 2. The strain of the top and bottom chords, as well as of diagonal and compressed vertical members in the investigated truss [Nastulski, 2016] was found to be higher in the case of calculations completed using traditional methods with the ideal model of the truss. The result might be over-sizing of the truss members when they are calculated in such a way (Table 1). The situation was different for the tension members, as a higher strain result was obtained in the

Figure 1. Elements of a model for analysis of a rod structure (example) [PN-EN 1995]
model generated with the TrussCon software. The difference resulted from the fact that the TrussCon software accounted for the bending moment occurring in the truss members. This does not occur in a model with pin joined diagonals. In the analysed example, the traditional calculations for the compressed elements and chords erred on the safe side, but ignored the bending moment of the tension members which could result in exceeding load-bearing capacity of the element. This situation could have occurred in each case where considerable strain is placed on the sections. This happens frequently when designing a structure.

![Figure 2. The static scheme of a truss model using TrussCon software](image)

**Table 1.** Comparison of results obtained with traditional calculation methods and TrussCon [Nastulski, 2016]

<table>
<thead>
<tr>
<th>Compared value</th>
<th>Value obtained using traditional calculation methods</th>
<th>Value obtained using RoofCon/TrussCon software</th>
<th>Value ratio</th>
</tr>
</thead>
<tbody>
<tr>
<td>Strain of the top chord</td>
<td>50.6%</td>
<td>32.9%</td>
<td>1.54 : 1</td>
</tr>
<tr>
<td>Strain of the bottom chord</td>
<td>70.2%</td>
<td>52.9%</td>
<td>1.33 : 1</td>
</tr>
<tr>
<td>Strain of the compressed diagonal members</td>
<td>40.8%</td>
<td>24.9%</td>
<td>1.64 : 1</td>
</tr>
<tr>
<td>Strain of the compressed vertical members</td>
<td>33.8%</td>
<td>27.4%</td>
<td>1.23 : 1</td>
</tr>
<tr>
<td>Strain of the tension diagonal members</td>
<td>21.0%</td>
<td>24.8%</td>
<td>1 : 1.18</td>
</tr>
<tr>
<td>Maximum vertical reaction of the support</td>
<td>11.428 kN</td>
<td>11.68 kN</td>
<td>1 : 1.02</td>
</tr>
<tr>
<td>Total final deflection</td>
<td>11.5 mm</td>
<td>13.2 mm</td>
<td>1 : 1.15</td>
</tr>
</tbody>
</table>

It has to be emphasized that only specifications for timber were compared, as it was not possible to model connectors using the software which had not been dedicated to specifying dimensions of nail plate trusses. Complex design of a truss includes also connections used in the joints. The TrussCon software allows for additional analysis of other conditions related to the experience of the supplier and the long-term observation and analysis of structure, such as, e.g., the plate overlapping the chord.

An additional advantage of using software applications dedicated to the design of trusses joined with nail plates, relates to the possibility of designing customised structural solutions, such as wedges in supporting nodes, or roof eaves. Eaves are often used in construction, but tend to be overlooked in the design of trusses or in the case of simplified dimensioning due to complexity of such calculations. This often leads to underestimating internal forces.

The issue of installation the truss on a support and the problem of additional pressure are also important for the process of designing timber structures and should not be ignored. A wedge can be used to avoid very wide supports which are necessary due to the low
compression strength perpendicular to the grain (fig.3). This enables loads from the top (chord) to be transferred to the bottom one via a larger surface.

**Figure 3.** The use of a wedge between the top and bottom chords in the support area

Taking into account a wedge in the process of specifying dimensions reduces the strain of the chords, which enables the structure to be designed in a more cost-effective way.

A separate issue is related to applying appropriate standards in designing nail plate trusses. The relevant standard [PN-EN 14250] refers to Eurocodes, both to all parts of the PN-EN 1991 Eurocode, as well as to the [PN-EN 1995] Eurocode. This means that the PN-EN14250 standard does not apply where loads are calculated according to the old Polish Standards. PN-EN14250 specifies requirements in relation to the timber to be used for the truss, such as deviations from rectilinearity or curvature. What is more important for the design process is that minimum dimensions of sections are specified as follows:

- thickness of 35mm for all elements,
- height of 68mm for chords,
- height of 58mm for vertical and diagonal stabs.

This is not the only constraint when it comes to specifying dimensions. The minimum thickness of a section is indicated, depending on the length of the element and its strength, as there is also the risk of damaging the truss during transport and installation. This relationship is described by means of the following formula:

\[
b = \frac{1.8l^2}{f_{m,k}}
\]

where:
- \(l\) – the overall length of the member, in meters (m),
- \(f_{m,k}\) – is the characteristic bending strength in (N/mm\(^2\)).

In case of older structures, for which calculations were made in accordance with the old Polish Standard, such a condition did not exist. This may pose a problem in situations where changes to be introduced into the structure require new calculations. This relates both to the situation where the building needs adaptation to Eurocode requirements, as well as in emergency situations, which call for reinforcement of an existing structure.
SPATIAL ANALYSIS

Global analysis of the three-dimensional structure should not be ignored in the designing process. Roof trusses joined with nail plates are usually made of 45-70 mm thick timber and the trusses comprising them, which often reach 5 m or more in height at the roof ridge, are slender and may lose stability. It is thus important to include an appropriate bracing system when designing the structure so as to provide it with required global stability.

CONCLUSION

It must be emphasized that uncritical adoption of schemas for structural analysis of timber structures should be avoided. Static scheme determines the way the distribution of forces in the structure is depicted and is closely related to the method used for joining elements. Application of pinned and quasi-rigid joints in timber structures is not easy or straight-forward [Jasieńko et al, 2011].

Using traditional, simplified methods for static calculations for nail plate trusses may result in significant over-sizing the structure, and consequently, inefficient use of timber. Accounting for flexibility of connectors and bending of elements resulting from eccentric forces is time-consuming [Olsson, 2010] and for this reason, often ends up being neglected by structural designers. It should be noted that changes in standards, which provided the basis for calculations and design, have resulted in more restricted requirements for timber structures joined with nail plates [Kotwica, 2016]. For this reason, when structures built several years ago are subjected to verification on the occasion of, e.g., change of use, the result is usually that the load-bearing capacity limit has been exceeded for both timber and nail plates.

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Streszczenie: Wybrane aspekty projektowania wiązarów kratowych łączonych na płytki kolczaste. W artykule poruszone kwestie związane z wymiarowaniem wiązarów kratowych zastosowaniem programów Robot Structural Analysis oraz TrussCon. Wykazano różnice wynikające z przeprowadzania obliczeń statycznych przy użyciu metod tradycyjnych do wyznaczania sił w kratownicy oraz z uwzględnieniem podatności węzłów. Poruszone również kwestie związane z koniecznością zastosowania właściwych norm oraz wskazano problemy, które mogą wystąpić przy analizie statycznej istniejących obiektów oraz projektowaniu wzmocnień konstrukcji (koniecznych np. przy przebudowie obiektu), które zostały zaprojektowane w oparciu o wycofaną, polską normę.

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Research on the effect of elevated temperature on the resistance to bending spruce wood impregnated with silica containing fire retardant

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Abstract: Research on the effect of elevated temperature on the resistance to bending spruce wood impregnated with silica containing fire retardant. The paper presents results of the study on the effect of high temperature on the resistance to bending spruce wood impregnated with aqueous solution containing SiO$_2$ nanoparticles at a concentration of 400 ppm. Impregnation was carried out with the vacuum method of vacuum pressure of 0.07 MPa. Based on the results of the studies, it should be noted that impregnation with aqueous solution containing SiO$_2$ nanoparticles adversely affects the spruce wood resistance to bending both at room temperature and after initial exposure at 230 °C. The results of the tests conducted at 230° C show that impregnation has unfavourable effect on sampling stiffness. There is an increase in the statistical coefficient of variation in elevated temperature conditions.

Keywords: resistance, fire-protection impregnation, spruce wood

INTRODUCTION  
Wood is one of the basic materials used in building and structures engineering. In micro structural terms, wood is a heterogeneous cell composite consisting of cellulose, hemicellulose, lignin and other less essential constituents. The largest volume of wood is cellulose, it consists of long carbon chains, which are the most important because of the wood resistance. Hemicellulose consists of branched amorphous polymers, fills the area between cellulose and lignin in the wood structure. The “agglomerating” factor of the wood structure is lignin, which is an amorphous polymer responsible for cohesion [Younsi R., 2010, Deka K., 2011]. Building wood has a number of beneficial physical and mechanical properties. It is also characterized by a small specific gravity. Structural elements made of wood are characterized by excellent durability with relatively little effort required to maintain them. One of the main wood disadvantage is its flammability. Under fire conditions, the wooden structure is subjected to force exertion and to thermal impact caused by the fire. Simultaneous interaction of these factors affects the distribution of stresses throughout the volume of the structural element while limiting its load-bearing capacity. High temperatures in the fire cause decohesion of the structure, a noticeable reduction in the strength of wood occurs at temperatures exceeding 65ºC [Cheek M., 2011]. At cellular level, degradation of dried cellulose occurs at temperature about 300ºC. In the case of hemicellulose degradation occurs in the temperature range of 150 ÷ 200ºC, moreover decomposition of lignin constituting the cohesion of wood structure occurs at temperatures of 220 ÷ 50ºC [Kamdem D.P., 2002].

Nowadays research is carried out in many research institutes to increase the resistance of wooden structures to high temperatures. In terms of wood protection against heat, fire retardants are most commonly used. By reason of the way of use impregnates are divided into two basic groups [Bednarek Z., 2010, Tomak E.D., 2012]:

- penetrating into the wood, most of which include saline or phosphorus, boron, magnesium, ammonium, nitrogen and urea compounds. These impregnants are used for in-depth impregnation of the wooden elements with vacuum or vacuum-pressure method.
• the second group consists of surface-active agents (coatings) in the form of paints, lacquers, aqueous solutions and thin plates. These agents form a protective layer on the wood surface and are used in places where it is not necessary to preserve the natural colour and the jar of wood. [Nagrodzka M., 2011]

The aim of the researches to determine the strength of modified and non-thermally modified spruce wood under simulated thermal fire conditions, within the range below the wood's ignition temperature, while simultaneously carrying out the static load.

MATERIALS AND METHODS

Samples for testing, measuring 20x20x300mm, were made from domestic spruce wood. The sample material was seasoned for four years. All samples were made of main material. The selected sawn timber was cut into strips and dried in a chamber dryer for 14 days. Prior to impregnation the samples were stored for six months in a dry room and their moisture content was about 12%. Impregnation of samples was done in a vacuum dryer SPU-200. This device works at temperature range of 20 °C to 200°C and has a permissible vacuum of 0.099MPa. Samples were impregnated with an aqueous solution containing SiO_2 nanoparticles. The detailed properties of the impregnant are shown in Table 1.

Table 1. Detailed physical and chemical properties of SiO_2

<table>
<thead>
<tr>
<th>Properties of impregnant</th>
<th>(Description / value)</th>
</tr>
</thead>
<tbody>
<tr>
<td>Appearance</td>
<td>White powder</td>
</tr>
<tr>
<td>Odour</td>
<td>lack</td>
</tr>
<tr>
<td>Size of particles</td>
<td>10-20 nm</td>
</tr>
<tr>
<td>Initial melting point</td>
<td>1600°C</td>
</tr>
<tr>
<td>Initial boiling point</td>
<td>2300°C</td>
</tr>
<tr>
<td>Volumetric density</td>
<td>0.011 g/ml</td>
</tr>
</tbody>
</table>

Prior to impregnation, there was prepared a solution in an electromagnetic mixer. Concentration of the prepared solution was 400 ppm. Then the solution was poured into a container to ensure complete immersion of the samples. Then the samples were freely placed in the solution for 20 min. And then they were placed in a vacuum dryer chamber. Impregnation of samples prepared for strength testing was carried out with vacuum method for 15 min using a vacuum of 0.07 MPa. After this process they were removed and dried at ambient temperature.

SAMPLES HEAT TREATMENT

Prior to the commencement of the strength test, the sample was subjected to thermal treatment. Preliminary studies were conducted to determine the experiment temperature range and determine the minimum exposure times of the samples at elevated temperatures to allow temperature equalization throughout the volume of the whole sample. To measure temperature in the geometric centre of the sample there were made hole in the samples during the pre-testing. Heating time was determined as the time after which the thermocouple placed inside the sample indicated the temperature assumed in the test plan.

The starting temperature for the tests was normal temperature of 20°C. The limit temperature was 230°C, which is close to the ignition temperature of the wood surface. Sample heating was performed in intermediate-temperature chamber furnaces type PK 1100/5. The standard temperature-time curve was adopted as a basis during the preheating.
testing. After placing the samples in the furnace, thermocouples were mounted on the outer surface of the selected sample. Pattern of heating samples is shown in Figure 1.

Heating samples was divided into two stages. In the first stage lasting 10 minutes, samples were heated to 230°C. After this time, the second stage followed, where they were heated at a fixed temperature for 12 minutes. This time was minimal to obtain a temperature of 230°C in the total volume of the heated samples. The furnace operation was done using a controller with a measuring computer and ThermoPro software. The temperature was recorded with using the PC equipped with a measurement card.

STRENGTH TESTS

Static bending strength tests were carried out on the universal strength machine LaboTest 6.100SP.1-2-2300, which allows the static force to be applied and maintained in a vertical system at a fixed level. The maximum static power produced by the machine is 100kN.

The device is equipped with three measuring heads, while during the test there was used measuring head of nominal value of 10kN. In the study was used a traverse speed range of 2mm/min. The sample loading pattern for strength tests is shown in Figure 2.

Samples were placed on the table in a symmetrical manner as shown in the diagram. The sample prepared in this way was subjected to a flexural load. The whole process was recorded. The maximum bending force was the value of the force at which the sample was destroyed. This equation was used to calculate bending strength:
where: \( P_{\text{max}} \) – destructive force [N]
\( l \) – spacing of supports [mm]
\( b \) – sample width [mm]
\( h \) – sample height [mm]

**ANALYSIS OF OBTAINED RESULTS FROM RESEARCHING**

There were used 60 samples for strength tests. For each temperature assumed in tests, there were conducted research for 15 samples impregnated with SiO\(_2\) and not impregnated. Statistical parameters of the obtained strength test results are given in Table 1.

<table>
<thead>
<tr>
<th>Statistics (N = 15)</th>
<th>( E_{bw} ) [MPa]</th>
<th>( R_{bw} ) [MPa]</th>
<th>( f_{\text{max}} ) [mm]</th>
<th>( R_{Bzniszcz} ) [MPa]</th>
<th>( f_{\text{zniszc}} ) [mm]</th>
<th>( t_{\text{badania}} ) [s]</th>
</tr>
</thead>
<tbody>
<tr>
<td><strong>Not impregnated sample -20°C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>8040</td>
<td>68,1</td>
<td>8,6</td>
<td>48,3</td>
<td>12,2</td>
<td>74,6</td>
</tr>
<tr>
<td>( s )</td>
<td>980</td>
<td>4,4</td>
<td>1,1</td>
<td>3,5</td>
<td>4,1</td>
<td>26,7</td>
</tr>
<tr>
<td>( \nu )</td>
<td>12,2</td>
<td>6,5</td>
<td>13,1</td>
<td>6,6</td>
<td>33,8</td>
<td>11,6</td>
</tr>
<tr>
<td><strong>Impregnated sample SiO(_2) - 20°C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>7670</td>
<td>66,2</td>
<td>11,7</td>
<td>46,4</td>
<td>13,7</td>
<td>77,7</td>
</tr>
<tr>
<td>( s )</td>
<td>1270</td>
<td>10,3</td>
<td>1,3</td>
<td>7,2</td>
<td>3,7</td>
<td>23,3</td>
</tr>
<tr>
<td>( \nu )</td>
<td>19,7</td>
<td>15,9</td>
<td>15,5</td>
<td>16,0</td>
<td>29,2</td>
<td>29,3</td>
</tr>
<tr>
<td><strong>Not impregnated sample- 230°C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>8160</td>
<td>72,3</td>
<td>6,9</td>
<td>50,2</td>
<td>8,7</td>
<td>59,8</td>
</tr>
<tr>
<td>( s )</td>
<td>1020</td>
<td>8,2</td>
<td>1,6</td>
<td>6,6</td>
<td>1,9</td>
<td>11,6</td>
</tr>
<tr>
<td>( \nu )</td>
<td>18,2</td>
<td>11,6</td>
<td>13,9</td>
<td>11,7</td>
<td>15,3</td>
<td>19,2</td>
</tr>
<tr>
<td><strong>Impregnated sample SiO(_2)- 230°C</strong></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
</tr>
<tr>
<td>( x )</td>
<td>7050</td>
<td>62,2</td>
<td>9,9</td>
<td>43,8</td>
<td>11,2</td>
<td>43,4</td>
</tr>
<tr>
<td>( s )</td>
<td>1420</td>
<td>16,2</td>
<td>2,1</td>
<td>11,4</td>
<td>3,7</td>
<td>21,4</td>
</tr>
<tr>
<td>( \nu )</td>
<td>17,8</td>
<td>26,1</td>
<td>34,3</td>
<td>26,6</td>
<td>49,8</td>
<td>49,3</td>
</tr>
</tbody>
</table>

Table 2 shows the results of bending strength, elasticity and deformation of spruce wood. The following parameters are given: \( N \) – sample size, \( E_{bw} \) – modulus of elasticity in flexure, \( R_{bw} \) – bending strength, \( f_{\text{max}} \) – specimen bending under max force (with \( R_{bw} \)), \( R_{Bzniszcz} \) – strength at failure, \( f_{\text{zniszc}} \) – deflection of the sample at destructive power (under \( R_{Bzniszcz} \)). There was given average value, standard deviation and percentage of variation coefficient for each parameter.

Impregnated with SiO\(_2\) and non-impregnated samples was imaged with scanning microscope (Phenom Pro G2) in order to compare their surface.
RESULTS

Impregnation with SiO$_2$ solution affects the strength properties of wood. This happens both at normal and elevated temperatures after initial exposure. There was observed an increase in the average deflection values of the impregnated samples compared to untreated, especially for those which was not subjected to initial thermal treatment. Taking into account samples, which was not subjected to initial thermal treatment, the strength of non-impregnated samples is about 5% greater than thse impregnated. One more difference can be observed in the strength test of preheated samples at 230°C. As a result of the studies, it was observed that impregnation with aqueous solution containing SiO$_2$ nanoparticles adversely affects the strength of the spruce wood. In this case, the strength of non-impregnated samples is higher than the impregnated as much as some 16%. There were also observed changes in the modulus of elasticity. For the samples tested at 20°C, the effect of the impregnate on this parameter is no significant. Results of tests conducted at 230°C indicate the unfavourable effect of impregnation on the samples stiffness. There is an increase in the statistical coefficient of variation in elevated temperature conditions, which is characteristically for results of bending strength ($R_{bw}$) and modulus of elasticity (E). This state of affairs is unfavourable and translates directly into the increase of structural failure. The use of impregnates had little effect on the change in mass of the samples, both at normal and elevated temperatures.

REFERENCES


Streszczenie: Badanie wpływu podwyższonej temperatury przy wytrzymałość na zginanie drewna świerkowego impregnowanego środkiem ogniochronnym zawierającym krzemionkę.

W pracy przedstawiono wynik badań wpływu podwyższonej temperatury na wytrzymałość na zginanie drewna świerkowego impregnowanego wodnym roztworem zawierającym nanocząstki SiO2 o stężeniu 400 ppm. Impregnacja została przeprowadzona metodą próźniową stosując podciśnienie wynoszące 0,7 atm. Na podstawie przeprowadzonych badań należy stwierdzić, że impregnacja wodnym roztworem zawierającym nanocząstki SiO2 niekorzystnie wpływa na wytrzymałość drewna świerkowego przy zginaniu zarówno w temperaturze normalnej jak i po wstępnej ekspozycji w temperaturze 230°C. Wyniki badań przeprowadzonych w temperaturze 230°C wskazują na niekorzystny wpływ impregnacji na sztywność próbek. W warunkach podwyższonych temperaturach widoczny jest wzrost statystycznego współczynnika zmienności.

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Effect of spent coffee grounds additions on the mechanical properties of the epoxy composites

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Abstract: Effect of spent coffee grounds additions on the mechanical properties of the epoxy composites. A commercial epoxy system was doped with spent coffee grounds (SCG) as filler. The effect of SCG on the mechanical properties of the compositions were examined. It was found that non-extracted SCG decreased MOR by 5 to 18% and increased modulus of elasticity from 6296 MPa for the neat epoxy to 18000 MPa for 2.5%-SCG doped system. The additions of defatted SCG after extraction resulted in dramatic loss in the mechanical behavior of the composites.

Keywords: epoxy, composite, coffee

INTRODUCTION

The global export of the roasted coffee exceeded 914 000 tonnes in 2013 (FAOSTAT 2017). A majority of this quantity generates wastes in the form of spent coffee grounds (SCG) that cannot be neglected and should be considered a renewable feedstock in green energy production (Kondamundi et al. 2008), biodiesel production (Go et al. 2016) or as biomass for composting (Liu and Price 2011). Alternatively, SCG seems to be a source of bioactive compounds (Cavin et al. 2002). The SCG is known to contain significant amounts of the lipids in the form of coffee oil and coffee wax rich in sterols and tocoferols (Wilson et al. 1997; Speer and Kölling-Speer 2006).

Spent coffee grounds can also be used in design of new materials and composites. One of the simplest approaches is to use as filler in epoxy matrix. However, the content of lipids varies from 7 to 17% in dependence on the species: ca. 10% for Robusta (Coffea canephora Pierre ex Froehner) and ca. 15% for Arabica (Coffea arabica L.) (Speer and Kölling-Speer 2006).

It was hypothesized that lipids weaken the interaction of SCG with the epoxy matrix. Thus, in order to verify the hypothesis and describe the effect of spent coffee grounds additions on the mechanical properties of the epoxy matrix, a series of SCG-doped epoxies were tested for flexural modulus of rupture and modulus of elasticity.

MATERIALS AND METHODS

A commercial epoxy resin of viscosity 28 Pa·s (25°C) and tetraethyleneamine (TETA) as a hardener were used in the experiments. Spent Arabica (Coffea arabica L.) coffee grounds were added to the epoxy system at 2.5% and 5.0% ratio. The epoxy compositions were cured for 24 hrs at ambient temperature in the silicon casts to form specimens of dimensions 10 × 6 × 110 mm³. Specimens were conditioned at ambient temperature for 5 days before testing.

SCG was subjected to extraction in a Soxhlet apparatus (chloroform/acetone = 4/1, v/v) for 4 hrs to remove the lipids and extractives.

Modulus of elasticity (MOE) (determined from the slope of the linear elastic phase at the steepest slope) and flexural modulus of rupture (MOR) were measured on an INSTRON 3369 universal testing machine (Instron Corp., MA), at 2.0 mm/min bending rate and analyzed with Instron IX™/s software (Instron Corp., MA, USA).
The composite materials – including epoxies – are usually designed from at least two materials: a matrix and reinforcement. The latter is in the form of filler doped in bulk (short fibers, powders, nanopowders etc.) or as separate layer of a long fiber or fabric (glass fiber, carbon fiber etc.). The interfacial interactions on the filler-matrix boundary govern the mechanical properties of a composite and have a dominant effect on its behavior, durability and the area of application. The main factors that determine resultant adhesion on the boundary are chemical composition of the materials, their free surface energies and topography/morphology as well (McMahon and Ying 1982).

Roughness of material is a recognized factor that contributes to an increased interface area. From the adsorption theory of adhesion it is well known that the adhesive interactions are maximized when a perfect wetting of substrate occurs (i.e. contact angle 0°) (Pocius 2002). The requirement is met when wetting liquid and substrate exhibit strong intermolecular interactions. That is why a fatty material with low free surface energy is hydrophobic and weakly interacts with polar adhesives (matrices) because of the presence of weak non-polar boundary layer.

Thus, keeping in mind that spent coffee grounds (SCG) contain significant amounts of lipids and proteins (Speer and Kölling-Speer 2006), the effect of SCG addition as filler on the flexural properties of an epoxy composition was examined. The resultant MOR is shown in Fig. 1. It is apparent that both extracted and non-extracted SCG reduced the bending strength of the composite. When compared to the neat epoxy reference, the decrease reached 5% and 18%, respectively, for 2.5% and 5.0% addition of the non-extracted SCG. More severe decrease in MOR was observed for the extracted SCG – 76% and 87%, respectively, for 2.5% and 5.0% addition. It is likely that removal of fats accompanied extraction of proteins that could possibly be reactive toward epoxy functions. Subsequently, the interactions of SCG with the epoxy matrix were dramatically weakened and no reinforcing effect was found at all.

In Fig. 2 the variations in MOE are presented. It is clear that additions of the non-extracted SCG markedly increased modulus of elasticity from 6296 MPa for the neat epoxy to

![Figure 1. Modulus of rupture (MOR) of the tested epoxy compositions](image-url)
18000 MPa and 15400 MPa which is a 2-3-fold increase. The values of MOR and MOE for the neat epoxy remain coherent with those reported in the literature for the unmodified epoxy systems (Gordon and Fakley 2003). One sees that the dose of non-extracted SCG (2.5% or 5.0%) had no statistically significant effect on improvement in MOE. What is important, the extracted SCG decreased MOE of the composites. Thus, it is demonstrated that the inherent brittleness of neat epoxy was reduced by the non-extracted filler, while the extracted SCG deteriorated the mechanical properties of the composite again.

Decreased brittleness and stiffness of the epoxy doped with non-extracted SCG manifested in slight (6%) increase in specimen displacement at break (Fig. 3), while load at break remained intact (Fig. 4). As seen in Figs. 3 and 4, the extracted SCG dramatically reduced both displacement and load at break of the specimens which indicates loss in cohesion within the matrix.

![Modulus of elasticity (MOE) of the tested epoxy compositions](image1)

**Figure 2.** Modulus of elasticity (MOE) of the tested epoxy compositions

![Displacement at break of the tested epoxy compositions](image2)

**Figure 3.** Displacement at break of the tested epoxy compositions
CONCLUSIONS

The obtained results indicate that the SCG possibly acts as inert filler exhibiting low interactions with the matrix which rendered its lowered bending strength coming from inhomogeneity and discontinuity of the material.

On the other hand a positive effect of non-extracted SCG addition on the modulus of elasticity of the filled epoxy compositions come from a higher ability of the material to dissipate the stress and, subsequently, results in increased MOE. However, the effect of the extracted SCG on the mechanical behavior of the composites was always negative.

Due to initial character of the presented results, in order to describe and explain the interactions of SCG with epoxy matrix, further more detailed investigations including the analysis of composition of the SCG extracts, free surface energy of the phases and SEM analysis of the SCG morphology are necessary.

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Streszczenie: Wpływ dodatku pozostałości mielonej kawy na właściwości mechaniczne kompozytów epoksydowych. Handlowy system epoksydowy został domieszkowany pozostałościami mielonej kawy (SCG) pełniących rolę wypełniacza. Określono wpływ domieszek na właściwości mechaniczne kompozycji epoksydowych. Wykazano, że dodatek nie ekstrahowanego SCG obniżył MOR o 5 do 18%, natomiast spowodował poprawę modułu sprężystości z 6296 MPa dla referencyjnego epoksydu do 18000 MPa dla systemu z dodatkiem 2,5% SCG. Dodatek odtłuszczonego, ekstrahowanego SCG we wszystkich przypadkach powodował dramatyczne obniżenie właściwości mechanicznych kompozytów.

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The effect of thermal treatment of spruce wood on its fire performance characteristics

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Abstract: The effect of thermal treatment of spruce wood on its fire performance characteristics. The focus of this article is the assessment of the effect of thermal treatment of spruce wood (Picea abies L.) on its reaction to fire. The monitored test specimens were thermally modified at three temperatures, 160°C, 180°C and 210°C. The test specimens were sorted according to density, quality and the annual ring direction. During the test, they were subjected to a direct flame for 10 minutes, after which the flame was removed and the testing continued for 5 minutes. The monitored characteristics were weight loss and burn rate. We compared the measured results with results obtained from a set of test specimens that were not thermally treated - solid wood. The measured results show that thermally treated spruce wood has a lower weight loss when burning than untreated spruce wood. The lowest weight loss of 3.976% was observed in spruce wood thermally modified at a temperature of 160°C. The burn rate was the fastest in spruce that was thermally modified at 210°C, which started to burn vigorously at 30 s and again at 140 s; the graph shows 2 significant peaks. The highest burn rate of spruce thermally modified at 180°C was observed between 140 and 160 seconds. Spruce thermally modified at 160°C showed a similar burn rate as untreated spruce at 20°C. After 10 minutes, when the testing continued without a direct flame, the burning continued to die down for another 30 seconds, and then the weight stabilized and only changed slightly within the range of 0.05 g.

Keywords: spruce wood, thermal treatment, flame test, burn rate, weight loss, flammability

INTRODUCTION

Wood is a flammable material in any form, as a raw material or product, and at every stage of processing (Reinprecht 2012). The regulation of wood parameters in relation to fire is especially necessary for wood constructions and all the wood products that they contain.

In terms of utilization and processing, wood has both positive and negative characteristics arising from the number of its positive qualities as well as shortcomings, which are given by its natural origin, anisotropy and faults that occur during growth. Its shortcomings primarily include its low resistance to abiotic factors and its high flammability. For this reason, we are looking for ways to suppress these shortcomings and expand the utilization of wood. The only perspective expanding method is the thermal modification of wood. In thermal treatment of wood, the wood is deliberately exposed to high temperatures in various technological operations, the most frequent method being oven drying at a temperature ranging between 50 – 240 °C (Reinprecht and Vidholdová 2008, Wilkowski et al. 2011). Thermal modification of wood increases its resistance to biodegradation and weathering, improves its aesthetic value, dimensional stability, thermal insulation and acoustic properties, and reduces its hygroscopicity (Martinka et al. 2013). The major drawback of thermally modified wood is the deterioration of most of its mechanical properties.

No additional chemicals are used in the thermal treatment process, and the material is harmless to the environment (Metsä-Kortelainen et al. 2011). Thermal and hydrothermal changes occur in wood during thermal modification at high temperatures ranging between
150°C - 220°C - 260 °C (Kačíková and Kačík 2011). Significant changes in the chemical structure of the wood begin to occur at temperatures above 150 - 170°C (Baysal et al. 2014, Dubovsky et al. 1998). The given temperatures begin to cause significant changes in the chemical structure of polysaccharides, lignin and accompanying substances (Yinodotlgör and Kartal 2010, Bekhta and Niemz 2003).

The thermal resistance of the basic components of wood varies. Hemicelluloses are the least resistant to thermal decomposition. They decompose in the temperature range of 170–240 °C. Cellulose is more resistant than hemicellulose. The decomposition of cellulose is minimal up to the temperature of 250 °C. In the temperature range of 250–350 °C, intense thermal decomposition of cellulose occurs. Lignin is the wood component that is most resistant to thermal decomposition. Active decomposition of lignin occurs at a temperature of 300-400 °C. When the wood burns, the bonds of its basic components decompose and their chemical composition changes, producing many byproducts. (Kačík, Marková 2000).

However, we are missing knowledge about the fire performance of thermally modified wood. Fire characteristics are particularly important in wood construction (ThermoWood Handbook 2002). Although there are studies of the issue of the fire performance of thermowood (Martinka et al. 2013), information about fire retardant treatment of thermowood is lacking. For testing wood's reaction to fire, like other construction materials, established standard procedures defined in European standards are used. For determining the fire characteristics of thermally modified wood, we have created our own evaluation method. The test simulates the natural process of wood burning with a flame source, a sustained inlet of air and a free flow of flue gases.

MATERIALS

The research consisted of two basic sets of test samples. The first set of samples consisted of thermally modified spruce (Picea abies L.), at 160°C, 180°C and 210°C, and the second set of samples consisted of untreated spruce wood. The sizes of radially cut test specimens intended for determining the weight loss and burn rate were 100 mm, 20 mm and 200 mm (Fig.1). Samples were conditioned to a moisture content of 8% (ϕ = 40 ± 3% and t = 20 ± 2 °C), which represents the final moisture content of wood products used in interiors according to EN 942 (2007) and ČSN 91 0001 (2007). For the testing we used a self-made apparatus from common laboratory equipment (Fig. 2), and we used the software BalanceLink from Mettler Toledo, Swisse for recording the results of continuous weighing. The main assessment criterion is the weight loss of test specimens, which is calculated using Equation 1.

\[ \Delta m = \frac{m_i - m_f}{m_i} \times 100 \]  

(3)

were, \( \Delta m \) is the weight loss (%), \( m_i \) is the sample's weight before the test (g), and \( m_f \) is the sample's weight after the test (g).

We calculated the burn rate according to Equation 2.

\[ v = (m_t - m_{t+10} / m_{t+10} \times 10) / 100 \]

where, \( m_t \) is the weight (g) at time \( t \), \( m_{t+10} \) is the weight(g) of the sample 10 seconds later, and \( m_{t+10} \) is the weight(g) of the sample at time 0.
RESULTS

The results show that thermally modified spruce wood had a lower weight loss when burning than untreated spruce wood. Tab 1. The lowest weight loss of 3.976 % was found in spruce wood thermally modified at 160°C, followed by wood thermally modified at 210°C and 180°C. Unmodified spruce had a weight loss of 4.178% 10 minutes into the test. The best results were achieved in spruce modified at 160°C. All other modified spruce samples exhibited better values than untreated spruce. Fig.3

As the test continued from the 10th to the 15th minute without a direct flame, the weight loss continued from the value measured after 10 minutes by 0.54% in untreated spruce wood, by 0.52% in spruce treated at 160°C, by 0.46% in spruce treated at 180°C, and by 0.33% in spruce treated at 210°C. These results indicate that a higher thermal modification temperature slows the weight loss in wood in spontaneous burning and decay.
Table 1 Sample table

<table>
<thead>
<tr>
<th>Sample labelling, thermal modification temperature</th>
<th>Weight loss after 10 min. in %</th>
<th>Weight loss after 10 min. in %</th>
<th>Rozdiel úbytku hmotnosti od 10 minúty a 15 minúty v %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Spruce P20</td>
<td>4.718</td>
<td>5.261</td>
<td>0.543</td>
</tr>
<tr>
<td>Spruce P160</td>
<td>3.976</td>
<td>4.505</td>
<td>0.529</td>
</tr>
<tr>
<td>Spruce P180</td>
<td>4.478</td>
<td>4.941</td>
<td>0.463</td>
</tr>
<tr>
<td>Spruce P210</td>
<td>4.310</td>
<td>4.640</td>
<td>0.33</td>
</tr>
</tbody>
</table>

Figure 3. Weight loss graph spruce P

The burn rate was highest in spruce thermally modified at 210°C, which started to burn vigorously at 30s and 250s. The graph in Figure 4 shows 2 significant peaks. The highest burn rate of spruce thermally modified at 180°C was observed between 140 and 160 seconds. Spruce wood thermally modified at 160°C exhibited a similar burn rate to that of untreated spruce at 20°C.
CONCLUSIONS
The experiment confirmed two facts: It verified the suitability of laboratory equipment and methods of testing the modification (e.g. thermal) of spruce wood, as well as other wood species. The presented method has so far only been used to evaluate retardant treatments. The method has proven to be sufficiently sensitive to evaluate the changes that occurred in the thermal treatment of wood.

ACKNOWLEDGEMENTS
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The effect of thermal modification of teak wood on its fire performance characteristics

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²) Department of Fire Engineering, Faculty of Security Engineering, University of Žilina, Žilina Slovak Republic;

Abstract: The effect of thermal modification of teak wood on its fire performance characteristics. This article is aimed at evaluating the effect of thermal modification of teak wood (Tectona grandisL. f.) on its reaction to fire. The monitored sets of test specimens were thermally modified at a temperature of 160°C, 180°C and 210°C. The test specimens were produced from commercial teak lumber. During the burning, we observed a weight loss every 10 seconds for the period of 10 minutes. The monitored characteristics were weight loss and burn rate. We compared the measured results with results obtained from a set of test specimens that were not thermally treated. The measured results show that thermally treated teak wood has a significantly higher weight loss when burning than untreated teak wood. The control sample of untreated teak wood had a weight loss of 4.55%. The greatest weight loss of 13.48% was found in teak wood that was thermally treated at 180°C. Teak wood thermally treated at 160°C had a weight loss of 12.77%, and teak wood treated at 210°C had a weight loss of 11.22%. The teak wood started to burn very quickly 20-30 seconds into the test. Vigorous burning occurred at 70 - 90 seconds, where the highest burn rate was observed. The burning then slowed down, followed by another increase in the burn rate. The graph shows two peaks on each curve; the first initial peak, followed by the burning peak and subsequent repeated smaller peaks. The most significant peak was produced by teak wood thermally treated at 160°C, which burned vigorously but briefly at 200 seconds.

Keywords: teak wood, thermal modification, burning, weight loss, burn rate

INTRODUCTION

Classification of wood in natural durability classes according to EN 350 places teak in Class 1 - very durable, along with Iroko, Afzelia, Afromosia, Merbau. Thanks to the essential oil and rubber that teak wood contains, it has a better capability of withstanding natural elements than any other wood species. It has the ability to resist cracking, curling and rotting. It is tough, with a medium weight and average hardness. Teak is used as construction wood for exterior and interior building components with high demands for the durability of shapes and joints. In house construction, it is used for roofs, doors, window frames, flooring including parquets (mostly in hospitals) and for stairs. (Pánek 2015) Like all wood, teak wood is also flammable and it burns in any form (raw material, components, or proucts) and at each processing stage (Reinprecht 2012). The regulation of wood parameters in relation to fire is necessary mostly for wood buildings and their components, as well as other wood products made from teak. Fire characteristics are particularly important in wood construction (ThermoWood Handbook 2002). Although there are studies of the issue of the fire performance of thermowood (Martinka et al. 2013), information about fire retardant treatment of thermowood is lacking. Standard procedures defined in European standards are used to test the flammability of wood. We chose a non-standardized method for determining its fire performance. The test simulates the natural process of burning wood with a flame source, sustained inlet of air and free flow of flue gases. During the burning, we observed a weight loss every 10 seconds for the period of 10 minutes. We also calculated the burn rate from the measured values.
MATERIALS

The research consisted of two basic sets of test samples. The first set of samples consisted of thermally modified teak wood (*Tectona grandis* L. f.) at 160°C, 180°C, 210°C; the second set of samples consisted of untreated teak wood. The test samples were cut from commercially produced timber. The direction of the grain varied; most of the samples had a radial - tangential structure of annual rings. The sizes of test samples intended for determining weight loss were 90 mm, 20 mm and 200 mm (Fig.1). The sizes of test samples intended for determining the burn rate were 100 mm, 20 mm and 200 mm (Fig. 1). Samples were conditioned to a moisture content of 8 % (ϕ = 40 ± 3 % and t = 20 ± 2 °C). For the testing, we used a self-made apparatus from common laboratory equipment (Fig. 2), and we used the software BalanceLink from Mettler Toledo, Swisse for recording the results of continuous weighing. The main assessment criterion was the weight loss of test specimens, which is calculated using Equation 1.

\[ \Delta m = \frac{m_1 - m_2}{m_1} \times 100 \]  

(3)

were, \( \Delta m \) is the weight loss (%), \( m_1 \) is the sample's weight before the test (g), and \( m_2 \) is the sample's weight after the test (g).

We calculated the burn rate according to Equation 2.

\[ v = \frac{(m_t - m_{t+10} / m_{t0} \times 10)}{100} \]

where, \( m_t \) is the weight (g) at time \( t \), \( m_{t+10} \) is the weight (g) of the sample 10 seconds later, and \( m_{t0} \) is the weight(g) of the sample at time 0.

Figure. 1. Test specimens: a) weight loss and burn rate
RESULTS

The measured results show that thermally treated teak wood has a higher weight loss when burning than untreated teak wood. **Tab 1.** The smallest weight loss of 4.553 % was observed in teak wood without thermal treatment. Thermally modified teak wood has a significantly higher weight loss during burning. Teak wood modified at 210°C had a weight loss of 11.219%, teak wood modified at 160°C had a weight loss of 12.77 %, and the highest weight loss was observed in teak modified at 180°C. The progression of the weight loss is shown in **Fig.3.**

<table>
<thead>
<tr>
<th>Sample labelling, thermal modification temperature</th>
<th>Weight loss after 10 min. in %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Teak P 20</td>
<td>4.553</td>
</tr>
<tr>
<td>Teak P160</td>
<td>12.77</td>
</tr>
<tr>
<td>Teak P180</td>
<td>13.481</td>
</tr>
<tr>
<td>Teak P210</td>
<td>11.219</td>
</tr>
</tbody>
</table>

The burn rate graph **Fig.4.** shows that teak without thermal treatment started to burn vigorously three times during the test, which is represented in the graph by three peaks. All teak wood samples started to burn very vigorously as early as 70-90 seconds into the test, which is expressed in the graph with a rise in the curves. Each type of thermal modification had an initial small peak, followed by two additional peaks between 100 and 300 seconds. After 300 seconds the flame stabilized. The fastest burn rate was observed in teak wood that was thermally modified at 160°C. Teak wood modified at 180°C and 210°C had a similar progression.
Fig.3. Weight loss graph teak P

Fig.4. Teak wood burn rate graph P

Fig.5. Teak P 20°C after test

Fig.6. Teak P 160°C after test

Fig.7. Teak P 180°C after test

Fig.8. Teak P 210°C after test
CONCLUSION
Thermal treatment process on the teak wood raises its flammability. The fastest burn rate was observed in teak wood that was thermally modified at 160°C. The beginning burning processin progress of all test samples was very similar. Between 100 – 300 seconds started new burning and thermal treatment teak wood burned intensively than untreated wood.

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Streszczenie: Wpływ modyfikacji termicznej drewka tekowego na jego właściwości pożarowe. Celem pracy jest określenie wpływu modyfikacji termicznej drewna Tectona grandis L.f. na

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Contemporary conceptions on wooden architecture conservation as exemplified by the Temple of Diana in the Park-and-palace complex of the Royal Łazienki Museum

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Abstract: Contemporary conceptions on wooden architecture conservation as exemplified by the Temple of Diana in the Park-and-palace complex of the Royal Łazienki Museum. The article presents the results of conservation works, performed in the Temple of Diana in the Royal Łazienki. A conservation inspection was performed to determine the state of preservation of the object. Wood-decaying factors causing damage to the Temple were determined. On this basis, a conservation program was established by making a classification of the damaged elements depending on their state of preservation. Some were left and chemically protected, others had to be replaced with new elements. Contemporary methods and means used in the conservation works in the object were described.

Keywords: biodegradation of wood, wood, wooden architecture, conservation works

INTRODUCTION

According to the rules of the conservation work doctrine, all conservation work performed on monumental buildings should preserve to the highest possible level the original monumental material and should be reversible. For this reason, the species of wood used in construction of the building was determined and the construction itself was examined (Krajewski and Witomski 2015). At the same time, the importance of minimalisation of chemical impact on the environment leads to a reduced application of chemical preservatives. However, in the case of wooden architectural objects, the above mentioned assumptions are not always possible in practice. Wooden buildings are exposed to atmospheric factors, such as moisture, which leads to the growth of fungi and insects, so unconventional solutions are sometimes required. This results in the necessity of recognising the wood-decaying factors present in the building, causing damage to its construction. Those factors may reappear and cause again similar biodegradation of wood, as some species persistently stick to favourable conditions (Witomski 2006, Karyś 2014). To eliminate their reappearing in the building, it is necessary to elaborate an informed conception.

The aim of the conservation works, performed in 2010-2012, was to evaluate the state of preservation of the object, to identify the biodegradation factors, to determine the range of damage, and to elaborate a conservation program. The range of provided works included indispensable replacement of destroyed elements, patching and consolidating of partly destroyed elements, chemical protection of elements exposed to moisture and fungal attack, and protection of the whole building from moisture.
MATERIAL AND METHODS

The object of the performed conservation works was the Temple of Diana in the Park-palace Complex of the Royal Łazienki Museum. The temple is a detached, one-storey, rectangular building in the type of peripteros (Fig.1). The cella of the temple is surrounded with a single colonnade consisting of 16 columns of Ionic order. The cella is based on framing, covered with a horizontal boarding, imitating banded rustication, finished with mat white oil paint. The inner walls are finished with plaster on cane. Faux vault is placed on boarding. Front facade (on the south side) contains double panel doors. In the back (on the north side) similar, yet blind, doors are placed. On each of the sides (east and west) two Polish-type windows are placed. The columns, made from solid wood trunks, were covered with canvas and glass net, finished with synthetic plaster. The building has no cellar, its brick foundations, providing a plinth of the building, are equipped with a ceiling-type ventilation system. Around the plinth, stone bands are placed with gutters. On the plinth, a wooden stylobate is placed, providing a basis for the colonnade. The gable roof is leaned against a wooden rafter. Its sheathing is made from copper plate. The building has no rain gutters or downpipes.

The determination of the factors causing wood biodegradation was performed in situ as well as using samples taken for laboratory examination. The observation was performed macroscopically and using a stereoscopic microscope with small magnification (up to 8 times), also with the help of palpation. During the determination of fungi species, anatomic formations such as mycelium and fruit body were observed, as well as some features of wood decay – the colour and the type of cracking. In the case of insects, the classification was based on the appearance of galleries of wood boring insects larvae (their size and shape, as well as their contents, especially excrements) and the shape and sizes of exit holes. An important criterion in this classification was the knowledge of biological conditions of a given species – its habitat preferences, such as wood species, age of the wood, the area of the wood (sapwood vs heartwood), its moisture content, the presence (or lack of) fungi, temperature characteristics (heating of wooden elements) – determining the presence of a given species in a particular area.

RESULTS AND DISCUSSION

During the inspection of the building, white rot of wood and brown rot of wood were observed in the wooden stylobate, caused by Basidiomycota fungi. On the surface of the boarding, fruit bodies were observed of the Peniophora gigantea fungi, causing white rot of wood. The species is considered as a common fungi species, often observed in buildings (Witomski 2006, Karyś 2014).

In the bases of wooden columns areas of brown rot were observed, as well as areas of wood destroyed by wood boring insects larvae. Basing on characteristic features of decay, i.e. dark brown discolouration of the wood with simultaneous small cracking, as well as on the analysis of conditions prevailing in the attacked elements – alternate periods of humidification and drying, and high temperatures present in heated elements – the species causing brown rot of the wood was determined as the Gloeophyllum sepiarium fungus.
In the areas attacked by the fungus or exposed to humidification, feeding of the larvae of beetles from the Anobiidae family was observed, namely *Anobium pertinax* L. and *Xestobium rufivillosum* De Geer. Both the species are commonly observed causes of damage in wooden building constructions (Krajewski 2006, Krajewski 2014).

In the wooden beam inside the architrave, some inactive spots of brown rot of wood were observed, as well as places of insect feeding (Fig. 2). Based on the look of galleries of wood boring insects larvae, it was ascertained that the destruction of the roof truss was caused by the old house borer larvae (*Hylotrupes bajulus* L., Cerambycidae, Coleoptera).
During the conservation works, the generally advised rule of minimal possible intervention was applied (Krajewski and Witomski 2006, Rouba 2016, Witomski et al. 2016). A total replacement of the foundations of the building was necessary (Fig. 3). The wooden construction of the temple was leaned against metal scaffolding, the old foundations were disassembled and replaced with new ones, protected with both vertical and horizontal insulation (Fig. 4). Additionally, to achieve a better draining of water, the foundations were covered with bucket foil (Fig. 4) and filled up with coarse sand, easily transmissive for water. The underpinning was equipped with ceiling-type ventilation. The conservation works in the wooden parts of the building were limited to replacement of the wooden stylobate and column bases. Those elements had been permanently exposed to rainwater and thus to a rapid fungal decay. As both the planks in the stylobate and in the column bases had not been original ones, it was decided to replace them with new ones, produced from wood which had been pressure-treated with Wolmanit preparation. Applying wood saturated in its whole volume with wood preservatives in places particularly exposed to moisture is obligatory. As for the trunks of wooden columns, mostly original ones, yet exposed to capillary suction of water from the stylobate, it was decided to impregnate them with Adolit Borpatronen preparation by means of bullet method (Fig. 5). Also, the wooden architrave, dating from 1980s, was replaced with a new, impregnated one. The partly damaged carpentry construction of the roof was repaired with replacing elements in areas weakened by biodegradation. As for smaller defects in the area of the crowning of cornice, they were carefully filled with small pieces of wood (Fig. 6).
After finishing the conservation works of the wooden structure of the temple, whole building was covered with oil paint. Tapping method was applied.

Fig. 3. Conservation works on the new foundations. Steel scaffolding supporting the construction is visible

Fig. 4. Insulation of the foundations and covering with bucket foil
Fig. 5. New column bases made from pressure-treated wood and places of introduction of bullets in the wooden columns

Fig. 6. Careful work of patching the defects of the cornice
CONCLUSIONS
During the examination, factors were determined responsible for wood damage: among fungi, they were *Peniophora gigantea* and *Gloeophyllum sepiarium*, and among insects, they were the deathwatch beetle *Xestobium rufovillosum*, *Anobium pertinax* and the old house borer *Hylotrupes bajulus*.

According to the contemporary conservation trends, wooden elements cohesive enough to provide lifting force, were impregnated and left for further exploitation. The columns, exposed to moisture, were impregnated with preservative bullets. The partly damaged elements were filled with deeply impregnated wood, and destroyed elements were replaced with new ones, impregnated by pressure treatment.

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Assessment of working conditions in rural areas in local approach on the example of medium company

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Abstract: Assessment of working conditions in rural areas in local approach on the example of medium company The article attempts to assess the working conditions in the wood processing plants located in rural areas of Opole region on the example of a medium-sized plant. Level of awareness of the respondents concerning the occupational hazards in their industry was also examined along with to what extent the respondents abide applicable safety regulations.

Keywords: working conditions, sawmilling, rural areas.

INTRODUCTION

Working in a sawmill industry is characterized by relatively high occupational risk. Threats to life and health of workers in the wood processing plant are triggered mainly by difficult physical working conditions including excessive pollination, insufficient light intensity, excessive mechanical vibrations, unsuitable microclimate, noise exceeding the legal limit, contact with dangerous equipment and machines and necessity to use dangerous hand tools and sharp objects. In addition, inaccurate work organization, lack of full mechanization of machining operations and presence of harmful impregnating agents, preservatives and retardants are problems often reported in the sawmill industry. At the same time, due to the lack of adequate financial resources, the employees of wood processing plants frequently work on obsolete and depleted machinery park, which affect the overall assessment of working conditions.

OBJECTIVE, METHOD AND SCOPE OF THE STUDY

The main objective of the research was to identify the employees and employers’ opinions on the quality of working conditions. On this basis, the study attempted to evaluate working conditions.

The research was performed in a medium-sized company engaged in the processing of wood in Kluczbork districts. The company produces pallets and offering roof truss, scantlings, battens, soffit panel floorboards and terrace boards, garden furniture and pine bark. Over 10 years of its operation on the market, the company has become the leading manufacturer of wood products in Opole region. Its products are offered both on national and international markets. At the beginning of its operation, the company employed approximately 10 workers. With the development and growing range of products and services offered, further staff was employed. For several years, the average employment falls within the range 60-70 people. The questionnaire contained 20 questions. The research was conducted in May 2016. All manual workers (i.e. 52 persons) and seven persons holding managerial positions participated in the survey.

Based on the widely accepted classification of working conditions, the questionnaire’s questions comprised four basic issues. The first group of questions was related to motivation to undertake job in the audited company and job characteristics. The issues from the second group included activities connected with following safety rules and their usefulness in the opinion of respondents. The third group of questions concerned issues related to the
assessment of physical working conditions. The fourth group of questions included the opinion of respondents on the employment conditions and interpersonal relationships in the workplace.

COURSE, ANALYSIS OF SURVEY RESULTS

While analyzing data obtained in the survey, it can be noticed that in the examined plants, the advantage of respondents were men aged 35 - 52 years. These are mostly people with basic education level. The dominance of men in this particular branch of industry is primarily due to the specific nature of its operation, which often does not fit or is too strenuous for women (e.g. milling operation). In terms of job seniority in the analyzed company, a significant percentage (i.e. more than half of the employees) accounted for respondents with a relatively short job experience, i.e. up to 3 years. This presents a high rotation of workers, which can be caused by various factors both, internal and external (e.g. low remuneration). Moreover, it is worth noting that 1/5 of the employees were persons with extensive professional experience (i.e. employees with job experience exceeding 10 years). Seventy five percent of employees are residents of the villages, which undoubtedly is connected to the fact that plants are located in rural areas.

Workplace and its characteristics

One of crucial elements affecting the quality of working conditions are motives behind the decision to choose this particular job. The decision to take up employment in the analyzed company was influenced mainly by the fact of having job (opinion of 78% of employees) and the proximity of plant to place of residence (opinion of 70% of employees). Qualifications, education, development opportunities and financial benefits were definitely less important, an average every fifth employee believes so. Analyzing acquired data, it can be concluded that the respondents did not show too much initiative in job searching. Undoubtedly, the reason for this may be that both plants are located in relatively small towns, where it is harder to find work than in urban areas or more industrialized ones.

In order to perform the job characteristics, there have been made attempt to determine the employee’s position in a system: man - tool or machine – processed material and work organization manner. On this basis, it can be assumed that the respondents work both, using the machinery, as well as using simple and complex tools. Employees work solely in the single-shift system. More than half of the employees believe that the degree of difficulty in the use of machinery and equipment is marginal. Moreover, during the analysis of surveys, it was noted that job mainly requires physical effort being at the same time arduous.

Activities in the field of occupational health and safety and their usefulness

In the analyzed company, employees and their supervisors (100%) accordingly confirmed that they had been provided with the induction training. Unfortunately, in the field of periodic training, situation is not so clear, since workers opinions do not coincide with the replies of supervisors, according to whom periodic trainings apply to all employees. Provided trainings were usually understandable.

Moreover, based on questions relating to activities undertaken in the field of occupational health and safety and their usefulness, it can be also observed that according to most respondents (85.7% of supervisors and 77.7% of employees) OHS training can reduce the number of accidents at work. Unfortunately, every third employee confesses to violate health and safety rules. Supervisors noted this problem as well, admitting lack of consistent response in this matter. Interestingly, almost all respondents have believed that penalties should be imposed on employees who violate safety regulations, since their lack, as it occurs
in this particular company, do not activate change of behaviour. Respondents’ opinion on abiding working hours is a positive phenomenon - all respondents answered positively.

Accident threats

Threats of accidents occurring in the timber industry are the source of factors affecting the level of working conditions. They arise from reasons both directly and indirectly dependent on the man.

Analyzing the question concerning the reasons of accident risks in the workplace it can be concluded that the respondents mostly agree as to the causes of accident risks in the workplace. The most common answers were:

- inefficient machinery and equipment (opinion of 73.1% workers - 100% supervisors),
- violation of health and safety regulations (opinion 55.7% of workers and 85.7% supervisors),
- stress and family problems (opinion of 53.8% employees - 71.4% supervisors),
- negligence and irresponsibility of employees (opinion of 67.3% workers – 85.7% supervisors),
- overwork of employees (opinion of 61.5% employees – 57.1% supervisors).

Other factors (e.g. work in the evening hours, employee’s inattention, strenuous working conditions) in the opinion of all respondents play a minor role.

It should be noted that the high rate of factors directly attributable to the employees is not contingent upon the size of the company. It consists of many factors, among which one could list fast pace of life and lack of employees professional approach to their duties.

Factors affecting poor quality of working conditions

<table>
<thead>
<tr>
<th>No.</th>
<th>In your opinion, what does affect the poor quality of working conditions</th>
<th>employees</th>
<th>supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>work environment (such as excessive noise)</td>
<td>71.1%</td>
<td>85.7%</td>
</tr>
<tr>
<td>b)</td>
<td>work organization</td>
<td>40.3%</td>
<td>85.7%</td>
</tr>
<tr>
<td>c)</td>
<td>machinery park</td>
<td>44.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>d)</td>
<td>remuneration</td>
<td>73.1%</td>
<td>57.1%</td>
</tr>
<tr>
<td>e)</td>
<td>interpersonal relationships employee - superior</td>
<td>32.6%</td>
<td>71.4%</td>
</tr>
<tr>
<td>f)</td>
<td>providing personal protection equipment</td>
<td>44.2%</td>
<td>100.0%</td>
</tr>
<tr>
<td>g)</td>
<td>employees training</td>
<td>17.7%</td>
<td>60.0%</td>
</tr>
</tbody>
</table>

source: Own calculations based on surveys. It was possible to choose more than one answer.

In the opinion of supervisors, the quality of working conditions in general, is determined by all factors identified above, and in particular by a proper organization of the workplace, efficient machinery park, equipment and tools, and provision of personal protection equipment. On the other hand, employees believe that the level of remuneration and work environment are primary the priority. This may indicate the low awareness of employees on the factors responsible for the quality of working conditions.
Table 2. The structure of factors affecting poor working conditions occurring in the surveyed company; source: own calculations based on surveys. It was possible to choose more than one answer.

<table>
<thead>
<tr>
<th>No.</th>
<th>In your opinion, what does affect poor working conditions in your workplace?</th>
<th>employee(s)</th>
<th>supervisor(s)</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>work environment (such as excessive noise, pollination)</td>
<td>71,1%</td>
<td>71,4%</td>
</tr>
<tr>
<td>b)</td>
<td>inaccurate work organization</td>
<td>19,2%</td>
<td>14,2%</td>
</tr>
<tr>
<td>c)</td>
<td>machinery park contravening the requirements of safety rules</td>
<td>40,3%</td>
<td>14,2%</td>
</tr>
<tr>
<td>d)</td>
<td>too low remuneration</td>
<td>73,1%</td>
<td>28,5%</td>
</tr>
<tr>
<td>e)</td>
<td>inappropriate interpersonal relationships on the line employee - superior</td>
<td>21,1%</td>
<td>14,2%</td>
</tr>
<tr>
<td>f)</td>
<td>not providing personal protection equipment</td>
<td>17,3%</td>
<td>-</td>
</tr>
<tr>
<td>g)</td>
<td>lack of possibilities for employees training</td>
<td>17,3%</td>
<td>-</td>
</tr>
</tbody>
</table>

Considering the responses of supervisors, poor quality of working conditions mainly depends on factors related to the specific work environment in the sawmill industry. Whereas, other factors are at proper level or slightly deviate from the generally accepted standards. The workers’ opinions overlap only in relation to work environment. In addition, a considerable percentage believes that remuneration is too low and the machinery and tools do not meet occupational safety regulations which is significantly reflected in the quality of work. Other factors, though to a lesser extent, appear as well.

Use of personal protective equipment

Employer’s provision of personal protective equipment and at the same time using it by the employees play a crucial role, since it reduces significantly the risk of accident at work. Unfortunately, the analysis of responses clearly indicates that a considerable percentage of respondents is not aware of necessity to use personal protective equipment - every fifth worker pointed “I DO NOT KNOW” as an answer to the question “Is it necessary to use personal protective equipment at your workplace?”. This may indicate a lack information in this subject provided by the management team or unprofessional approach to the workplace by the workers, who often undergo appropriate training; however, they disregard it and do not pay much attention.

This is also confirmed by answers to the questions shown in table 3. Analyzing them, it can be said that 1/4 of employees have no idea whether the employer provides the necessary personal protective equipment, and more than 1/3 of employees uses them only from time to time. What is even more interesting is the fact that, not all supervisors have no idea whether their subordinates work in accordance with binding occupational safety rules. This attitude undoubtedly fosters misconduct of employees. Therefore, it can be concluded that the level of workers’ use of personal protective equipment, as well as management awareness in this subject is low, which in turn is reflected in the growth of occupational risk.
Table 3. The frequency of applicability of PPE by employees

<table>
<thead>
<tr>
<th>Does the employer provide adequate personal protective equipment?</th>
<th>employees</th>
<th>supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>no</td>
<td>don’t know</td>
</tr>
<tr>
<td>yes</td>
<td>no</td>
<td>don’t know</td>
</tr>
<tr>
<td>69,3%</td>
<td>5,7%</td>
<td>25,0%</td>
</tr>
<tr>
<td>100,0%</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Do you use personal protective equipment?  

<table>
<thead>
<tr>
<th>Do the employees use personal protective equipment?</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes, always</td>
</tr>
<tr>
<td>yes, sometime</td>
</tr>
<tr>
<td>no, never</td>
</tr>
<tr>
<td>yes, always</td>
</tr>
<tr>
<td>yes, often</td>
</tr>
<tr>
<td>no, never</td>
</tr>
<tr>
<td>don’t know</td>
</tr>
<tr>
<td>59,6%</td>
</tr>
<tr>
<td>34,6%</td>
</tr>
<tr>
<td>5,8%</td>
</tr>
<tr>
<td>33,3%</td>
</tr>
<tr>
<td>24,1%</td>
</tr>
<tr>
<td>-</td>
</tr>
<tr>
<td>42,6%</td>
</tr>
</tbody>
</table>

source: Own calculations based on surveys

Conditions of employment, interpersonal relations

The type of employment contract and remuneration issues are strongly influenced by the level of economic working conditions and thus they affect the assessment of working conditions in general. In the analyzed company more than half of employees is dissatisfied with the type of contract they have signed. Fixed-term contracts or contracts for an indefinite time but not full-time are the majority. Even more people is dissatisfied with the amount of their remuneration, which is slightly higher than the minimum wage. The opinion of supervisors is quite different in this regard. According to them, the employees receive adequate remuneration, consistent with education level, qualifications and skills.

Table 4. The structure of satisfaction with employment contract and the amount of received remuneration

<table>
<thead>
<tr>
<th>Are you satisfied with the signed contract?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>55,7%</td>
</tr>
<tr>
<td>44,3%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>Are you satisfied with the remuneration you receive?</th>
<th>No</th>
</tr>
</thead>
<tbody>
<tr>
<td>yes</td>
<td>69,3%</td>
</tr>
<tr>
<td>30,7%</td>
<td></td>
</tr>
</tbody>
</table>

<table>
<thead>
<tr>
<th>In which group would you place your remuneration?</th>
<th></th>
</tr>
</thead>
<tbody>
<tr>
<td>1000 – 2000 zł</td>
<td>23,1%</td>
</tr>
<tr>
<td>2001 – 3000 zł</td>
<td>65,4%</td>
</tr>
<tr>
<td>3001 – 4000 zł</td>
<td>11,5%</td>
</tr>
<tr>
<td>Higher than 4000 zł</td>
<td>-</td>
</tr>
</tbody>
</table>

source: Own calculations based on surveys.
The aim of subsequent question was to learn respondents' opinion regarding interpersonal relations in the company. Most of the employees and supervisors identified them as positive (almost 67% of employees and 80% supervisors). However, none of the respondents did identify them as excellent. All employees had divergent opinion concerning the answer, which suggests a very low level of interpersonal relations. Every fifth employee expressed such an opinion, whereas supervisors did not notice any irregularities in this regard.

Table 5. Overall assessment of working conditions in the opinion of employees and their supervisors

<table>
<thead>
<tr>
<th>specification</th>
<th>workers</th>
<th>supervisors</th>
</tr>
</thead>
<tbody>
<tr>
<td>excellent</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Very good</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>good</td>
<td>30,8%</td>
<td>85,7%</td>
</tr>
<tr>
<td>satisfactory</td>
<td>44,3%</td>
<td>14,3%</td>
</tr>
<tr>
<td>bad</td>
<td>24,9%</td>
<td>-</td>
</tr>
</tbody>
</table>

source: own calculations based on surveys

The last question in the questionnaire was supposed to assess overall evaluation of working conditions. By analyzing data, it can be concluded that the opinion of employees is far from the view of their supervisors, who evaluate it on a high level. As many as a quarter of respondents working physically consider working conditions simply as derogatory and undignified.

SUMMARY

The research allowed to collect relevant information on the basis of which the analysis and conclusions were formulated concerning the overall assessment of working conditions in the sawmill industry in rural areas of Opole Voivodship. The views on organizational and technical, economic and social conditions of work clearly show that the opinion of employees is significantly different from the supervisors’ opinion. This is also confirmed by the evaluation summarizing the general working conditions in the company. In addition, the analysis carried out, indicates that employees are not fully aware of factors determining the quality of work environment, and their often inappropriate behavior reduces the overall quality of working conditions. Unfortunately, it is often the fault of the lack of proper reaction from supervisors. Therefore, it can be concluded that working conditions in the analyzed company considerably deviate from accepted standards.

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Streszczenie: Ocena warunków pracy na obszarach wiejskich w ujęciu lokalnym na przykładzie średniej wielkości przedsiębiorstwa. W artykule podjęto próbę oceny warunków pracy w zakładach przerobu drewna usytuowanych na obszarach wiejskich województwa opolskiego biorąc pod uwagę opinię pracowników i ich przełożonych. Zbadano również poziom świadomości respondentów na temat ryzyka zawodowego w ich branży oraz to w jakim stopniu przestrzegają obowiązujące przepisy bhp.

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Organizational and technical working conditions as one of determinants of human capital - comparative study on the example of wood processing industry

KORNELIA POLEK-DURAJ

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Abstract: Organizational and technical working conditions as one of determinants of human capital - comparative study on the example of wood processing industry. The aim of the study is to characterize the quality of organizational and technical working conditions in the wood processing industry on the example of micro and medium-sized plants located in Opole Voivodeship. The important element was to present the differences between the two companies. At the same time, the author’s intention was to underline that in spite of the differences of organizational and technical working conditions in both companies, they are still on unsatisfactory level.

Keywords: organizational and technical working conditions, wood processing industry, human capital, health

INTRODUCTION

Wood processing industry is relatively specific branch of industry with regard to the presence of numerous threats to life and health of employees. In a significant extent, the organizational and technical working conditions determine it. In particular, such factors as: contact of workers with dangerous equipment and machines, difficult physical work environment, the need to use dangerous hand tools and sharp objects, improper organization of work, the lack of full mechanization of machining operations and presence of harmful impregnating agents, preservatives and retardants.

AIM AND SCOPE OF STUDY

The main objective of the survey was to identify the opinion of employees regarding the quality of organizational and technical working conditions employed in the wood processing industry in Opole Voivodeship and to demonstrate that micro-enterprises have a poorer performance than large companies do. In addition, an attempt was made to examine employee’s awareness on occupational risks and non-compliance with binding occupational safety and health. In the survey, particular attention was paid to questions relating to the interaction of health with the work environment.

The questionnaire was composed 30 questions, comprising four basic issues that allow general assessment of working conditions, including technical and organizational ones, i.e. organization of the nature of operations and its impact on the employee, the activities regarding compliance with the principles of workplace safety and health and its usefulness in the opinion of respondents, the assessment of material working conditions and self-assessment of workers’ health in relation to pollution of work environment.

The study was performed in two companies from wood processing industry located in rural areas of Opole Voivodeship. The survey was carried out in January 2016 in both companies. All employees (i.e. 10 employees from company no.1 and 56 employees from company no. 2) attended the survey.

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Characteristics of surveyed companies

The first company is a small family-owned sawmill founded in the 90s of the twentieth century. It specializes in the production of timber, Euro pallets and processing of hardwood and softwood. In addition, the plant sells firewood. Its main customers are individual domestic customers. Average annual employment is 10 employees.

The second company marks over 20 years of its existence on the market and has become the leading manufacturer of wood products in the Opole region. Its focus is production and sale of roof truss, square timber, patches, pine soffit, floorboards and terrace, garden furniture, pine bark and pallets. It offers its products to domestic and foreign customers, both small (i.e. individual customers) and large (e.g. developers). An average annual employment falls within the range of 50-61 people, depending on the number of orders and the season.

COURSE, ANALYSIS OF TEST RESULTS

Analysing the data obtained from the imprint, it can be stated that in a micro-enterprise, all employees are men between the ages of 22 to 58 years. In a larger company nine women are employed, the rest of respondents were mainly men aged 35 - 50 years. In both cases, these are generally persons with basic education. The dominance of men in the industry is primarily due to the specific nature of activities, which are often too heavy for women, since it requires physical effort. In sawmill only two employees have worked more than six years, the work experience of other usually does not exceed 18 months. This shows a high turnover of employees, which can be caused by various factors both internal and external (e.g. lack of a fixed-term contact). In the second company, also a large proportion (more than half of the employees) were respondents with a relatively short work experience, i.e. up to 5 years. However, there were some employees with work experience exceeding 15 years.

Nature of the work

In order to characterize the type of work and place of the worker in the production process, it can be concluded that more than half of the respondents in the Company no. 1 operates in a manual system (i.e. man - tool - work piece), while in the company no. 2 in the mechanized way (i.e. man - machine – work piece). In sawmill, none of the staff is working in the automated system, while every fifth person is working in that way in the other company. Similar case concerns shift work. Employees from company no.1 work in a single-shift system, with the exception when the orders are higher than planned. Then, additional temporary workers are employed on specific-task contract or mandatory contract and the staff works on two shifts, which happens on average twice a year. A completely different situation occurs in the second company, where the percentage of employees working in two or sometimes even three shifts (for extra orders) affects more than 1/3 of the employees. The special compatibility, of the responses, concerned questions determining the degree of difficulty in the use of machinery and equipment. The majority of respondents (over 60% of responses in both plants) stated that using machines and equipment is moderately complex. In their view, the work requires, above all, physical effort, is often tiresome, tedious and monotonous.

Employers’ actions in the field of occupational health and safety

In both surveyed companies, the employees accordingly stated that they had participated in induction training for positions held (100% response). Unfortunately, the situation is much worse in the micro-enterprise, if it comes to periodic trainings, where half of the respondents declared its absence, and in the medium sized company - every fourth respondent. Conducted trainings are usually understandable, but mostly theoretical.
Unfortunately, not all participants who took part periodic training were aware of their usefulness. In the case of company no.1 half of those surveyed, systematically taking part in various training courses, and in the second company, 1/5 of all employees do not realize that trainings are necessary as they contribute to increase awareness of occupational hazards and prevention of accidents at work. In addition, every third employee from micro-enterprise and every fourth from the medium-sized pleaded guilty to breaches of health and safety regulations. Interestingly, almost all the respondents of both companies (89% and 92%) believe that penalties should be imposed for employees who violate safety regulations. Positive phenomenons are the opinions of the respondents on compliance with working time. In both surveyed companies, respondents indicated no irregularities in this issue. The formal difference between companies is the lack of health and safety department in the microenterprise, but with such a small number of staff, the owner can perform these tasks, and it should not affect their effectiveness.

Accident risk factors affecting low quality of working conditions

Risks of accidents at the workplace arise from a variety of reasons, attributable to both the employee and the employer.

Table 1. Reasons for the risk of accidents at the workplace

<table>
<thead>
<tr>
<th>Question 8</th>
<th>Which of the following factors cause the threat of accidents at work?</th>
<th>Company no.1</th>
<th>Company no.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>strenuous working conditions</td>
<td>30.0%</td>
<td>20.8%</td>
</tr>
<tr>
<td>b)</td>
<td>faulty machinery and equipment</td>
<td>40.0%</td>
<td>35.3%</td>
</tr>
<tr>
<td>c)</td>
<td>negligence and irresponsibility of employees</td>
<td>60.0%</td>
<td>58.0%</td>
</tr>
<tr>
<td>d)</td>
<td>inappropriate health and safety training</td>
<td>20.0%</td>
<td>21.2%</td>
</tr>
<tr>
<td>e)</td>
<td>work in the evening hours</td>
<td>10.0%</td>
<td>18.1%</td>
</tr>
<tr>
<td>f)</td>
<td>overworked employees</td>
<td>40.0%</td>
<td>45.6%</td>
</tr>
<tr>
<td>g)</td>
<td>stress and family problems</td>
<td>30.0%</td>
<td>41.1%</td>
</tr>
<tr>
<td>h)</td>
<td>poor working conditions</td>
<td>20.0%</td>
<td>21.9%</td>
</tr>
<tr>
<td>i)</td>
<td>carlessness of employees</td>
<td>50.0%</td>
<td>55.7%</td>
</tr>
<tr>
<td>j)</td>
<td>failure to comply with health and safety regulations</td>
<td>60.0%</td>
<td>56.3%</td>
</tr>
<tr>
<td>k)</td>
<td>other</td>
<td>10.0%</td>
<td>2.3%</td>
</tr>
</tbody>
</table>

Source: Own calculations based on surveys. There was the possibility to choose more than one answer.

Analyzing the above data, it can be stated that the employees in the surveyed companies agree on the reasons for risk of accidents at the workplace. Most of these factors depend on them.

In the opinion of surveyed employees from both companies, poor quality of working conditions is determined primarily by excessive noise (opinion of 90% of employees of company no.1 and 83.9% of company no.2), various types of pollination (opinion of 70% employees of company no.1 and 85.7% 1 of company no.2 ) and chemical factors (i.e. multi-component mixtures of volatile organic compounds commonly used as a diluents of paints, varnishes and adhesives - the opinion of more than half of the respondents from both companies). In addition, a large percentage of the respondents pointed to the use of equipment that does not meet the requirements of health and safety regulations (2/3 of the employees of company no.1 and more than 1/3 of company no.2).
Accident rates

The consequences of improper and poor working conditions, especially technical and organizational working conditions are risks to health and life of employees. Largely they contribute to accidents at the workplace.

Table 2. Structure of accidents at the workplace, the period of incapacity, and qualifications of accident

<table>
<thead>
<tr>
<th>No.</th>
<th>Specification</th>
<th>Company no.1</th>
<th>Company no.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Question. 12. Have you been injured in your current workplace?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>yes</td>
<td>30,0%</td>
<td>12,5%</td>
</tr>
<tr>
<td>b)</td>
<td>no</td>
<td>70,0%</td>
<td>87,5%</td>
</tr>
<tr>
<td></td>
<td>Question 13. (there was a possibility to choose more than one answer-an answer is given in relative numbers in terms of the number of employees who were injured)</td>
<td>If yes, what was the reason of the accident?</td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>inappropriate material factor (so called technical factor – „t”)</td>
<td>60,0%</td>
<td>44,2%</td>
</tr>
<tr>
<td>b)</td>
<td>improper work organization (so called organizational factor – „o”)</td>
<td>40,0%</td>
<td>32,1%</td>
</tr>
<tr>
<td>c)</td>
<td>inappropriate human behavior (so called human factor)</td>
<td>60,0%</td>
<td>60,8%</td>
</tr>
<tr>
<td></td>
<td>Question 14. If yes, how long have you been on sick leave?</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>1-3 days</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>b)</td>
<td>4-28 days</td>
<td>-</td>
<td>71,4%</td>
</tr>
<tr>
<td>c)</td>
<td>more than 28 days</td>
<td>100%</td>
<td>28,6%</td>
</tr>
</tbody>
</table>

Source: own calculations based on survey.

Accident rate referred to the entire period of employment of a given respondent in the surveyed company. In the first case, the accident rate is fairly high, as for every tenth employees, with a relatively short seniority, up to \(\frac{1}{3}\) were injured during accidents at workplace, requiring long-term sick leave lasting over twenty-eight days. In the second company, the situation is much better. Every tenth worker was injured, most of which required short-term treatment. Accidents usually occurred due to improper human behavior and as a result of inappropriate material factor. This is consistent with the answers to the question about the existing danger of accidents.

Physical work environment

The physical work environment in the factories of timber industry is seriously contaminated both by physical and chemical factors. Out of all the harmful factors, only the most common were taken into account.
Table 3. Structure of harmful factors occurring at the workplace and their importance for health in the evaluation of surveyed employees

<table>
<thead>
<tr>
<th>Question. 20 i 21</th>
<th>Company no. 1</th>
<th>Company no. 2</th>
<th>Wśzz</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>question 20</td>
<td>question 21</td>
<td>Wśzz</td>
</tr>
<tr>
<td>noise</td>
<td>50,0%</td>
<td>40,0%</td>
<td>0,80</td>
</tr>
<tr>
<td>pollination</td>
<td>60,0%</td>
<td>30,0%</td>
<td>0,50</td>
</tr>
<tr>
<td>chemical factors</td>
<td>60,0%</td>
<td>30,0%</td>
<td>0,50</td>
</tr>
<tr>
<td>mechanical vibrations</td>
<td>10,0%</td>
<td>10,0%</td>
<td>1</td>
</tr>
<tr>
<td>insufficient lighting of a workplace</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>other</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: Own calculations based on surveys. There was the possibility to choose more than one answer.

(1) – Which of the following harmful factors occur at your workplace?
(2) – Which of these factors are cumbersome and / or harmful for you and your well-being and health?

Considering the results it can be noted that in both companies there is a positive correlation between the questions "about the presence of harmful factors" (Question 20) and "awareness of their impact on well-being and health" (question 21).

To carry out full and in-depth analysis of questions 20 and 21, it was used the so-called. "factor of awareness of health risks" (Wśzz). Its value was taken as the ratio of the number of interviewed employees who are aware of the impact of harmful factors on the health in regard to the total number of workers interviewed declaring the existence of these factors at the workplace. Given the above information, one can conclude that respondents in both cases, are not fully aware of the risks of factors harmful to health. Nevertheless, it should be noted that according to the results from the Company no. 2 the employees present greater awareness of this issue. It might seem that in the Company no.1 the value of awareness of health risks with regard to the mechanical vibrations is exemplary, but this is confusing and proves only the fact that only 1 in 10 employees knows that such a factor exists at workplace and it is not irrelevant to the well-being and health. Only in the case of noise and its effects, the respondents are aware of its negative impact on the well-being and health. Unfortunately, it is no longer so clear in relation to the risks of pollination, which, along with the noise are nuisance and harmful factors, most frequently occurring at the workplace.

Personal protective equipment

The use of personal protective equipment by the employees plays a crucial role, as it greatly reduces the degree of the accident risk. Unfortunately, the analysis of the responses clearly indicates that a significant percentage of respondents in the surveyed companies are not aware of that fact. It should be noted, however, that in larger company, the situation is better, but not enough to be able to say that the level of use of personal protective equipment by employees is satisfactory and adequately protects them during the work.
Table 4. The frequency of applicability of personal protective equipment for workers

<table>
<thead>
<tr>
<th>No.</th>
<th>Specification</th>
<th>Company no.1</th>
<th>Company no.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>Question. 26</td>
<td></td>
<td></td>
</tr>
<tr>
<td></td>
<td>What kind of personal protective equipment should be used at your workplace? (there was a possibility to choose more than one answer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>protective clothing</td>
<td>50,0%</td>
<td>65,0%</td>
</tr>
<tr>
<td>b)</td>
<td>head protection</td>
<td>30,0%</td>
<td>39,6%</td>
</tr>
<tr>
<td>c)</td>
<td>heating protection</td>
<td>50,0%</td>
<td>60,8%</td>
</tr>
<tr>
<td>d)</td>
<td>eye protection</td>
<td>20,0%</td>
<td>24,1%</td>
</tr>
<tr>
<td>e)</td>
<td>respirators</td>
<td>10,0%</td>
<td>17,5%</td>
</tr>
<tr>
<td>f)</td>
<td>limb protection</td>
<td>10,0%</td>
<td>9,7%</td>
</tr>
</tbody>
</table>

Question. 27 Do you use personal protective equipment?

a) yes, always 50,0% 66,1%
b) yes, rarely 30,0% 28,1%
c) no 20,0% 5,8%

Source: own calculations based on survey.

Self-assessment of respondents’ health state

In this question, aiming at gathering the views of respondents about their health, a four-scale was used. Based on the results, a comparison of health state of interviewed workers prior to starting work in the current company and on the day of completing the survey was performed.

Table 5. Assessment of health declared by the employee for the period prior to starting work and at the time of completing the survey

<table>
<thead>
<tr>
<th>No.</th>
<th>Questions 28 - 29</th>
<th>Company no.1</th>
<th>Company no.2</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>grading scale</td>
<td>Prior to starting work in the current company</td>
<td>Currently</td>
</tr>
<tr>
<td>a)</td>
<td>very good</td>
<td>50,0%</td>
<td>30,0%</td>
</tr>
<tr>
<td>b)</td>
<td>good</td>
<td>40,0%</td>
<td>50,0%</td>
</tr>
<tr>
<td>c)</td>
<td>satisfactory</td>
<td>10,0%</td>
<td>20,0%</td>
</tr>
<tr>
<td>d)</td>
<td>bad</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Source: own calculations based on survey.

In both companies, changes of workers health state were observed. In relation to the assessment prior taking a job in the current company, a significant percentage of respondents changed the assessment of their health state to worse. This can be a result of factors both professional and non-professional. A positive development is the fact that none of the staff determines the state of their health on the lowest level in the adopted scale.
Table 6. Structure of the factors causing the deterioration of health of workers

<table>
<thead>
<tr>
<th>No.</th>
<th>Question. 30 Does work in the current company has contributed to the deterioration of your health?</th>
<th>Company no.1</th>
<th>Company no.2</th>
</tr>
</thead>
<tbody>
<tr>
<td>a)</td>
<td>yes</td>
<td>100%</td>
<td>35.8%</td>
</tr>
<tr>
<td>b)</td>
<td>no</td>
<td>-</td>
<td>64.2%</td>
</tr>
<tr>
<td></td>
<td>If yes, what was the reason? (there was a possibility to choose more than one answer)</td>
<td></td>
<td></td>
</tr>
<tr>
<td>a)</td>
<td>harmful work environment</td>
<td>50%</td>
<td>49.5%</td>
</tr>
<tr>
<td>b)</td>
<td>arduousness of work.</td>
<td>50%</td>
<td>39.1%</td>
</tr>
<tr>
<td>c)</td>
<td>other (lifestyle, addictions etc.)</td>
<td>-</td>
<td>11.4%</td>
</tr>
</tbody>
</table>

Source: own calculations based on survey.

Taking into account the responses received in Company no. 1 it can be seen that exactly the same percentage of respondents who pointed to the deterioration of health condition by taking up a job in relation to the present day, believed that it occurred as a result of work in the current company. In the Company no. 2, this opinion is expressed by considerably less percentage of respondents (1/3 responses). The main reasons of health deterioration, in both companies, are harmful work environment and arduousness of work. Undoubtedly, it is related to the use of outdated technologies and machinery. Employees of the Company no. 2 also indicated other reasons not directly related to their work (e.g. health problems, family problems, fast pace of life).

SUMMARY

The views expressed in polls clearly illustrate that the organizational and technical working conditions in the surveyed companies are at unsatisfactory level, thus also the overall quality of working conditions leaves much to be desired. In the case of larger company, the situation is slightly better, as indicated by the response of its employees. However, these answers are also not good enough to be regarded as sufficient and corresponding fully with EU requirements. The analysis confirms the results of previous surveys on this issue, which clearly indicates that the level of working conditions in the wood processing industry is insufficient, which is particularly evident in the micro-enterprise, being the workplace for almost 40% of the total working population.

REFERENCES


Streszczenie: Organizacyjno - techniczne warunki pracy jednym z determinantów kapitału ludzkiego – badania porównawcze na przykładzie zakładów branży drzewnej. Celem opracowania jest próbna charakteryzowania jakości organizacyjno-technicznych warunków pracy w branży drzewnej województwa opolskiego na przykładzie mikroprzedsiębiorstw oraz średniej wielkości. Ważnym elementem jest przedstawienie różnic w tej kwestii pomiędzy badanymi firmami. Jednocześnie chciano wykazać, że pomimo występujących
rozbieżności organizacyjno-techniczne, warunki pracy w obu badanych przedsiębiorstwach są na niezadowalającym poziomie i wymagają działań naprawczych.

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Influence of direction of cutting on cutting forces and quality during milling laminated MDF

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Abstract: Influence of direction of cutting on cutting forces and quality during milling laminated MDF. The aim of the experiment was to examine the influence of different milling types on value of cutting forces and surface quality status of laminated MDF. There were two types of cutting blades. The first was brand-new and the second was completely worn. Another variable parameter considered in this experiment was feed rate. Cutting forces were measured in two axes, with their resultant calculated thereafter. Machined surface quality was determined by edge condition of examined material. The results revealed that, using a new tool, climb milling causes cutting forces value to be bigger than by up milling. Using a worn tool results in an entirely opposite scenario. However, for both milling types, cutting forces grow with increase of feed rate. Moreover, the experiment revealed that machined surface quality is better, when using conventional milling.

Keywords: milling, conventional, climb, cutting forces, quality of machined surface

INTRODUCTION

The processing of raw material into a finished product is a key aspect in the furniture industry. Milling, sawing and drilling are the basic ways of shaping wood based materials and are used for the production of furniture and parts of interior design [Duchnowski 1997]. Better use of the natural resource, which is the wood as well as wood-based materials, is one of many factors of sufficiently realized treatment in accordance with the technological assumptions. There are some certain parameters, which guarantee optimum adaptation of the most efficient machining process which is milling. The selection of machines, tools, material and determine the order of processing are important aspects in the planning phase of the treatment process. Also selecting appropriate machining parameters including direction, speed, feed rate and depth have the impact on conducting the most efficient and safe machining. One of the variables defined above, crucial to the quality of the treatment, is the ratio of feed in relation to the working direction. For many years in the metalworking industry, milling wherein the feed direction was opposed to the speeds vector was the most popular way of machining. It is the case forces occurring during cutting are in the opposite direction to the feed - conventional milling [Kuryjański 2011]. This way of milling was used due to the possibility of machine clearance elimination during machining. However, there are a large number of contraindications of application of conventional milling in metalworking.

Occurring compressive stress and tensile (respectively at the entry and exit of cutting tool), the local hardening of the material under high temperature and the strengthening of deformation degree are unwanted phenomena [Grzesik 1998]. Over the years and the development of research on the process of milling almost completely supplanted from the steel industry. Conventional cutting is recommended for cutting high carbon alloys, cast iron for example, and for harder metals with contaminated surfaces [Jemielniak 1998].

No publication focusing on examining the impact of the milling direction on cutting forces and surface quality of laminated MDF found at the moment. Most of the publications on this topic applies milling of solid wood or steel. This proves the validity to examine in an experimental way of this approach.
MATERIALS AND METHODS

The research was carried out on an industrial milling center Busselato Jet 130 (Italy 2004). MDF was milled with parameters shown in Table 1. The working tool was single blade milling head (Faba, Poland) with a diameter of 40 mm with a replaceable carbide KCR08 (submicron tungsten carbide) blade. Two types of carbide blades were used. The first: brand new with VBmax = 0,0mm, the other: used with VBmax = 0.2 mm. The spindle speed was chosen according to the manufacturer of milling head recommendation (www.faba.pl) and set to 18,000 rpm.

<table>
<thead>
<tr>
<th>Property</th>
<th>Value</th>
</tr>
</thead>
<tbody>
<tr>
<td>Density [kg/m³]</td>
<td>760</td>
</tr>
<tr>
<td>Static bending strength [N/mm²]</td>
<td>34</td>
</tr>
<tr>
<td>Modulus of elasticity [N/mm²]</td>
<td>4231</td>
</tr>
<tr>
<td>Resistance to axial withdrawal of screws</td>
<td>110</td>
</tr>
<tr>
<td>Tensile strength [N/mm²]</td>
<td>0.5</td>
</tr>
<tr>
<td>Hardness [HB]</td>
<td>5</td>
</tr>
<tr>
<td>Sand content [%]</td>
<td>0,009</td>
</tr>
</tbody>
</table>

The experiment was performed with three variations of feed per revolution: 0.1; 0.2; 0.3 mm / rev. In order to determine the forces generated during the milling, samples of material with dimensions of 150x100mm were installed on the measurement platform (Figure 1) equipped with a piezoelectric sensor. The sensor signal was directed to a signal amplifier (Kistler 5036) and then to a data acquisition card (National Instruments PCI-6111) in a PC computer. The analysis of the signals was carried out in the LabView environment.

![Figure 1. Scheme of the measurement system.](image)

To evaluate the quality of processing the test material was measured using Mitutoyo microscope TM-505. The study was conducted for five variants of feed per revolution: 0.1; 0.2; 0.3; 0.4; 0.5 mm / rev. For each variant of feed 10 samples were milled. After the milling process the quality indicator "A" was evaluated defining the degree of damage on the surface edge - Fig.2.
RESULTS AND DISCUSSION

It was possible to identify certain correlation between the degree of tool wear, the value of feed per revolution and the direction of processing. Analysis of these dependences allows for the formulation of several conclusions.

![Figure 3. Cutting force for VB_{max}=0,0mm](image3.png)

![Figure 4. Cutting force for VB_{max}=0,2mm](image4.png)

![Figure 5. Indicator A for VB_{max}=0,0mm](image5.png)

![Figure 6. Indicator A for VB_{max}=0,2mm](image6.png)
For a new tool (VBmax = 0 mm) climb milling causes the appearance of higher cutting forces than conventional milling. This dependence applies to all specific values of feed per revolution. For the used tool (VBmax = 0.2 mm) conventional milling causes the appearance of higher cutting forces than climb milling. This correlation applies to each test the feed per revolution just like for the new tool.

For a new tool conventional milling causes lower value of indicator “A” than in case of climb milling. This dependence applies to all specific values of feed per revolution.

In the case of used tools VBmax = 0.2 mm, the value of quality indicator A depends on the value of feed per revolution.

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Na podstawie uzyskanych wyników stwierdzono, że dla nowego narzędzia frezowanie współbieżne stawia większe opory skrawania niż przeciwbieżne. Przy użyciu zużytego narzędzia sytuacja wygląda przeciwnie. Przy czym, dla obydwu przypadków, wraz ze wzrostem posuwu na żąb opory skrawania wzrastają. Poza tym, można jednoznacznie stwierdzić, iż jakość obróbki jest lepsza z zastosowaniem frezowania przeciwbieżnego.

Słowa kluczowe: frezowanie, współbieżnie, przeciwbieżnie, siły skrawania, jakość obróbki

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Increasing the stiffness of glued laminated timber beams using glass fibre reinforced (GFRP) rods

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Abstract: Increasing the stiffness of glued laminated timber beams by glass fibre reinforced polymer (GFRP) rods. The paper is concerned with the possibility to strengthen the stiffness of a beam using GFRP rods, having assumed that they are pasted between the extreme edge layers of the beam. It allows for subjecting the beam so enhanced to four-sided mechanical processing. It was found out that strengthening a beam with rods increases its stiffness, and the size of this increase mainly depends on the diameter of and the number of used rods as well as on the kind of fibres of which they are made.

Keywords: glulam, stiffness, modulus of elasticity, GFRP rods, bending

INTRODUCTION
Manufacturing a large wooden structure requires using glued laminated timber beams. Despite this, in some cases, use of such material may be not sufficient. This is, for example, a case of beams of very large spans or beams of the cross-sectional areas bounded externally. Therefore, additional enhancements made of other materials are used, which after fixing constitute a kind of reinforcement, forming along with a wooden structure a reinforced beam. For this purpose have hitherto been used, among others, tapes that were glued to the bottom of a beam or pasted between the layers (Romani and Blass 2001, Brol 2009, Jasieńko et al. 2009,) as well as rods pasted into grooves located underneath or in the side of a beam (Rajczyk and Stachecki 2011, Yusof and Saleh 2010).

In the Department of Wooden Structures of Kazimierz Wielki University in Bydgoszcz, Poland the research is carried out to develop and implement new design solutions of wood beams reinforced with polymer rods containing glass or carbon fibres. One of them is strengthening a beam with polymer rods placed inside a beam (Patent Application No P. 395222 of 10.06.2011). This solution allows the formation of beams in which, firstly, reinforcing elements are not shown in any of its longitudinal sections, and secondly, they may be subjected to four-sided mechanical processing typical of wood beams. This paper is concerned with the effect of using GFRP rods to strengthen a beam on increasing its stiffness.

TEORETICAL CONSIDERATION
The following assumptions were made with respect to the model structures of glued laminated timber beams reinforced with fibrous polymers: beams are made of ‘horizontal glued laminated timber’, layers of a beam are made of the same species and of the same class of wood, fibrous polymers have a form of a rod of a circular section, rods are arranged symmetrically with respect to the horizontal and vertical symmetry axes of a beam’s section.

The cross-section area of an exemplar beam constructed in accordance with the made assumptions is presented in Fig. 1. Reinforcing rods are characterized by better mechanical parameters than wood, including higher modulus of elasticity and higher tensile strength. According to the flexural theory, these rods the more reinforce a beam, the more distant their axes are (distance \(e\)) from the symmetry axis \(x\) being an neutral axis of the cross-section. The rods in accord with the assumptions should be located inside the beam, first of all to protect them from damage when machining external planes of a beam and making openings and
grooves in those planes. As effective has been regarded the placement of the rods in the grooves made in two extreme upper and lower layers of a beam or in the grooves made only in the extreme edge layers. In the latter case, the distance $e$ of the rod’s axes from the $x$-axis increased by $\frac{1}{2}d$ ($d$ – diameter of the rod).

When making the analysis of the mechanical behaviour of a glued laminated timber beam reinforced with fibrous rods it has been additionally assumed: that beams deform themselves in accordance with the hypothesis of flat cross-sections, with a result of this being the lack of ‘slipping’ between the layers and between rods and wood, fibres in rods are continuous along their length, the effect of glue lines – both connecting the layers and rods with wood – on deformation and tension is negligible, wood and fibrous rods are linear-elastic materials, the moduli of elasticity of wood along fibres under tension and compression have the same values, the moduli of elasticity of fibrous rods under tension and compression have the same values.

Figure 1. Cross-section of the glued laminated timber beam reinforced with fibrous rods placed between extreme upper and lower layers of the beam

The stiffness $EI$ of the glued laminated timber beam reinforced with fibrous rods is the sum of stiffnesses of its components:

$$EI = E_dI_d + E_p \sum I_p$$

where: $E$ - beam’s modulus of elasticity in bending,
$I$ - second moment of area of the beam’s cross-section with respect to the $x$-axis,
$E_d$ - wood’s modulus of elasticity in bending,
$I_d$ - second moment of area of the ‘wooden’ part of the beam’s cross-section with respect to the $x$-axis,
$E_p$ - fibrous rods’ modulus of elasticity,
$I_p$ - second moment of area of the rod’s cross-section with respect to the $x$-axis.

The second moment of area of the beam’s cross-section is defined by the formula:
And the second moment of area of the fibrous rod’s cross-section with respect to neutral y-axis:

\[ I_p = \pi d^4 \frac{64}{4} + \pi d^2 e^2 \tag{3} \]

Considering the total \( n \) number of rods of the same \( d \) diameter and of the same \( e \) distance of their axes from the neutral x-axis of the beam’s cross section, the formula of the beam’s stiffness finally takes a form:

\[ EI = E_p \frac{BH^3}{12} + \left( E_p - E_d \right) n \pi d^2 \left( d^2 + 16e^2 \right) \tag{4} \]

The mechanical parameter of reinforcing rods that affects the beam’s stiffness is their modulus of elasticity \( E_p \). The dependence of the beam’s stiffness \( EI \) on this parameter, specifically the result of the subtraction \((E_p - E_d)\) of the moduli of rods and wood is linear, that is increases in \( EI \) are proportional to increases in \((E_p - E_d)\). Also similar is the dependence of the \( EI \) stiffness on the \( n \) number of reinforcing rods. In contrast, the dependence of the beam’s stiffness \( EI \) on the \( d \) diameter of reinforcing rods is nonlinear, that is increases in \( EI \) corresponding to successive increases in the diameters of rods are greater and greater.

**EXPERIMENTAL**

The objective of experimental research was to determine the effect of reinforcing glued laminated timber beams with glass fibre rods on the stiffness of a beam under bending. The beam constructed as shown in Fig. 1 was produced, with the following assumptions made: the beam’s dimensions are 80×160×3000 mm (\(B\times H\times L\)), the number of layers in beams is 8, the rods’ diameter is 8 mm, the number of rods in the beam is 4 (Fig. 2). Besides, a beam without reinforcing rods was also tested.

![Figure 2. Dimensions of the cross-section of the beam with reinforcing rods](image)

Examinations of the modulus of elasticity in bending were made in compliance with the PN-EN 408 standard. To determine the local \( E_{m,l} \) and the apparent \( E_{m,l} \) modulus of elasticity, the beams were loaded as shown in Fig. 3.
The local modulus of elasticity of the beams was calculated according to the following equation:

\[
E_{m,l} = \frac{3al_1^3 \Delta F}{4Bh^3 \Delta w}
\]  

(5)

where:
- \(E_{m,l}\) - local modulus of elasticity,
- \(a\) - distance between a loading position and the nearest support in a bending test,
- \(l_1\) - gauge length for the determination of modulus of elasticity,
- \(l\) - span in bending,
- \(\Delta F\) - increment of load,
- \(B\) - width of the cross section,
- \(H\) - height of the cross section,
- \(\Delta w\) - increment of deformation corresponding to \(\Delta F\).

The apparent modulus of elasticity was given by the equation:

\[
E_{m,g} = \frac{l_1^3 \Delta F}{BH^3 \Delta w} \left[ \frac{3a}{4l} - \left( \frac{a}{l} \right)^3 \right]
\]  

(6)

where:
- \(E_{m,g}\) - apparent modulus of elasticity,
- \(l\) - span in bending.

The beams’ stiffness \(EI\) was calculated according to the following formula:

\[
EI = E_{m,l} \frac{Bh^3}{12}
\]  

(29)

The speed of loading beams in tests to determine moduli of elasticity was equal to 0.48 mm/s. The load increments \(\Delta F\) ranged from 0.1 to 0.4 \(F_{max}\), where \(F_{max}\) was the predicted value of destructive force. The beam’s deflections were measured to an accuracy of 0.001 mm, basing on the lower surface of the beam.

The results of examination of moduli of elasticity in bending are presented in Table 1. The elasticity moduli of the beams with rods have higher values than those of the control beam. The local modulus of the beam reinforced with rods is higher than that of the control beam on average by 11.5\%, and the apparent modulus by 6.1\%. The stiffness \(EI\) of the beam with rods, calculated on the basis of the apparent modulus of elasticity, is greater than the stiffness of the control beam on average by 7.2\%.

Figure 3. Scheme of loading the beam
Table 1. Moduli of elasticity and stiffness of beams

<table>
<thead>
<tr>
<th>Kind of beam</th>
<th>Local modulus of elasticity, $E_{m,l}$ (GPa)</th>
<th>Apparent modulus of elasticity, $E_{m,g}$ (GPa)</th>
<th>Beam stiffness, $EI$ (kNm²)</th>
</tr>
</thead>
<tbody>
<tr>
<td></td>
<td>mean value</td>
<td>standard deviation</td>
<td>mean value</td>
</tr>
<tr>
<td>Reinforced</td>
<td>11.4</td>
<td>0.54</td>
<td>10.5</td>
</tr>
<tr>
<td>Control</td>
<td>10.2</td>
<td>0.68</td>
<td>9.9</td>
</tr>
</tbody>
</table>

Let’s compare the results of experimental researches with the results determined theoretically. The mean increase in the stiffness of the beams reinforced with fibrous rods as compared to the stiffness of the control beam is equal to 7.2 %, being only slightly different from the increase calculated using the formula (4), assuming $E_p = 40$ GPa and $E_d = 9.9$ GPa, that amounted to 8.1%.

CONCLUSIONS
1. Reinforcing glued laminated timber beam with rods containing glass fibres results in a significant improvement of its modulus of elasticity in bending as well as of its stiffness.
2. The experimentally determined increase in the stiffness of beams reinforced with fibrous rods relative to the control beam (unenhanced) is comparable to the increase calculated theoretically.
3. The proposed way of placing reinforcing rods may be used to produce beams later on subjected to mechanical processing.

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Streszczenie: Poprawa sztywności belek klejonych warstwowo za pomocą prętów GFRP. Artykuł dotyczy możliwości zwiększenia sztywności belek za pomocą prętów GFRP przy założeniu ich lokalizacji w zewnętrznych warstwach belki. Takie rozwiązanie umożliwia czterostronną obróbkę mechaniczną belki. Stwierdzono, że poprawa sztywności zależy od średnicy I liczny zastosowanych prętów oraz od materiału, z których są wykonane.

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The role of root aquaporins in tree response to drought

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Abstract: The role of root aquaporins in tree response to drought. Wood quantity and quality utilized in forest industry is highly dependent on trees growth conditions. Water availability is among the most limiting factors for forest trees growth. Therefore, considerable research efforts have focused on understanding drought resistance mechanisms in trees. Hydraulic conductivity of plant tissue plays an important role in drought response. Water transport involves a combination of apoplastic, symplastic and transmembrane pathways. Transmembrane movement of water is facilitated by aquaporins, group of membrane channel proteins. Differential expression of aquaporins between plant tissues and in response to abiotic stresses suggest that they play role in maintaining water balance in plants. This review discuss the functions of root aquaporins under drought conditions.

Keywords: forest trees, drought, aquaporins

INTRODUCTION

Wood production and wood quality are of utmost importance in forest industry. Wood quality has a significant impact on wood processing, end-product quality and marketing (Kellison et al., 1984; Zobel, 1984; Kellogg, 1989). In general, wood quality can be understood as wood having both positive and negative features influencing its further use (Jackowski, 1972). Actual value of wood is reflected by its physical and mechanical properties, such as density. This traits are closely related to structural properties of wood, particularly latewood share and annual rings width. Various tree species growing on different forest sites and in different conditions eventually present a wood quality influenced by various biotic and abiotic factors. The major abiotic stresses (drought, heat, high salinity and cold) negatively influence the survival and biomass production of ecosystems. Dehydration stress imparted by drought, salinity and temperature severity is the most prevalent abiotic stress that limits plant growth and productivity (Vorasoot et al., 2003; Jaleel et al., 2009; Thakur et al., 2010). Woody plants also have to continuously face severe constraints from both the soil and aerial environments. Growth stresses may cause defects in standing trees and felled logs, thus reduce wood yield and quality. Wood density has been considered the most important wood quality attribute. To a large extent, wood density determines the suitability of a species for a specific end use. High density wood is usually associated with high lumber strength and stiffness. It was shown that wood density is greatly sensitive to environmental conditions (Rozenberg et al., 2002; Bouriaud et al., 2005), especially to high or low temperatures. The decline of the temperature during the growing season can induce a reduction in lignin content in latewood, showing a marked effect of the temperature on the lignifications process. The co-occurrence of drought and warming lead to formation of wood with lower density. Drought, also, have negative impact on such aspect of trees health as susceptibility to pathogen or insect attack and vulnerability to damage from fire (Zhao and Running, 2010; Reichstein et al., 2013).

There was reported that drought is one of several environmental stresses that cause drastic changes in the growth, physiology, and metabolism of plants. Tree performance is
strongly limited by water shortage. Consequently, drought has been frequently discussed as a trigger of vegetation shifts and forest decline. The dry and hot summers of last years in Europe strongly affected forest ecosystems. Severe water shortage in forest was shown to decrease primary production (Ciais et al., 2005; Granier et al., 2007), lower amount of stored carbohydrates (Breda et al., 2006) and timing when carbon is fixed (Eilmann et al., 2011). It was shown that in inner Alpine valleys, where precipitation is low because of the rain shadow of the surrounding high mountains ranges, drought was found to be the main factor limiting growth (Eilmann et al., 2006, 2009). Moreover Peng et al. (2011) found that drought increased tree mortality in mature stands of the Canadian boreal forest. Understanding of impact of drought on tree growth and tree responses is crucial for developing efficient strategies for the preservation of forest trees growth. Drought can provoke tree responses from molecular to the forest stand level (Hamanishi and Campbell, 2011). This review covers the general plants strategies that enable plants adaptation to water stress conditions in respect to trees and we draw attention to the role of aquaporins in the root response to drought.

MAIN TREE STRATEGIES UNDER DROUGHT STRESS
Forest tree species are considered some of the most long-living organisms. They require water and mineral nutrients for achieving their life cycle. Because trees are sessile, they have to efficiently absorb water and mineral nutrients from their close surroundings. This function is mostly fulfilled by the root system, which shows remarkable ability to grow continuously and explore the soil for available resources. In higher plants such as trees, root water uptake is mediated by radial transport from the soil into xylem vessels through epidermis, cortex, endodermis and stele tissues. Once in vessels water flows axially towards the plant shoot. Long-distance water transport occurs through xylem, which is formed of specialized dead vessels while water uptake by roots and delivery to shoots is mediated by living tissues. During radial transport water can flow along cell walls structures (apoplastic path), or from cell to cell, along cytoplasmic continuities form by plasmodesmata (symplastic path) or across cell membranes. The latter way of water transport is called transcellular path and is dependent on aquaporins activity. Preservation of proper water status also require that aerial parts mediate a tricky trade-off with the atmosphere. Leaves absorb CO₂, a basic component for photosynthesis, and releasing water by transpiration. This exchange is realized and controlled by stomata, microscope pores located in epidermis of plants aerial parts. Transpiration can occur because of intense flow of water (sap) travelling throughout the plant body, from roots to the substomatal chamber where it evaporates. This stream is particularly useful to drive water and nutrient ascent to the uppermost part of the shoot. Controlling the intensity and direction of these flows is crucial for maintaining the whole plant water status. At the cellular level, the presence of a cell wall allows buildup of intracellular hydrostatic pressure (turgor) which provides a motive force for differentiation of cells and formation tissues. Since cell divisions in merystema and subsequent expansion growth of living cells determine plants growth and development, water status define metabolic activity of tree, its growth and development. However, during their long lifetime trees are exposed to different environmental conditions, in particular, lack of water. For tree survival at dry sites, the maintenance of an efficient water transport system is of particular importance as it avoids a drought-induced downregulation photosynthetic activity and keeps xylem water potential above cavitation thresholds. The control of the hydration of tissues within ranges that are compatible with their functionality is important for any tree species. Though, forest trees like other plants develop adaptations under water limiting conditions.

Recent studies suggest that plants have evolved a variety of strategies to cope with drought. These strategies can be divided into two group: drought avoidance and drought tolerance. First group enable plants to avoid low water potential. This strategies depend on
mechanisms that maintain the plants water level, such that the level of water uptake and water loss remain in balance. Water loss can be restricted by various processes relying on osmotic adjustment or the regulation of efficient stomatal control. If drought conditions occurs in longer term limited shoot growth is observed, which consequently lead to an increased root-to-shoot ratio. To elevate water uptake plants can increase growth of root fine, form deep taproots and accumulate of solutes to lower water potential in the root tissue. When drought level is highly severe and drought avoidance mechanisms are insufficient to cope with stress condition, plants activate mechanisms that enable them to tolerate water deficit. In order to protect tissues against cellular damage plants start to produce protective proteins e.g dehydrins. Dehydrins are a complex family of proteins directly related to water deficit. They are thought to act in protecting the cell metabolism during the stress, and have been subjected to different expression analysis in forest tree species (e.g. Bae et al., 2009; Vornam et al., 2011).

Trees seem to have evolved specific mechanisms of response to dry conditions. This group of plants are characterized by possession of potential for developing deeper root systems than herbaceous plants, although the depth to which soil water depletion occurs varies widely among species (Canadell et al. 1996; Eggemeyer et al., 2009) and sites (Meier and Leuschner , 2008). The root depth influences the capacity to extract water from different soils horizons, being lower at a juvenile phase. Esteso-Martinez et al. (2006) showed that the minimum seasonal water potential in a stand of Quercus faginea were much less negative in adult trees that in seedlings, which could explain that in seedling stems was found higher percentage of cavitation than in adults organisms. Consequently, the investment of large amount of reserves in the development of deep and large root system may be considered to be crucial for trees growing in water-limiting stands (Bloom et al., 1985). Other way to adapt to water stress is higher partitioning of biomass to belowground organs, as observed from inter-population variation within some forest tree species (Aranda et al., 2010). However, the production of a large root system may condition the amount of reserves that can be used to develop shoot for capture of aerial resources (Valladares and Pearcy, 2002). To reach compromise between growth and survival under water deficit plants adjust root to shoot ratio which is recognized as a stress response strategy. In the other hand, the production of an expanded root system does not ensure survival of trees under severe drought conditions. In fact, soil drought induces a loss of root hydraulic conductivity which may be caused by changes in root anatomy (Nobel and Lee, 1991), root xylem cavitation (Sperry and Ikeda, 1997) or changes in the expression of aquaporins (Secchi et al., 2007). In order to recover root conductivity usually plants have to reconstruct root system which require the investment a new resources (Lo Gullo et al., 1998). Some woody plants recover hydraulic conductivity by refilling xylem conduits through the generation of positive water pressure in root tissues (Melcher et al., 2001). In the literature, there are proposed novel mechanisms for recovering the hydraulic conductivity (Zwieniecki and Holbrook, 2009) but they need to be studied during in vivo experiments.

The shedding of expendable organs has been recognized as an another mechanism to cope with drought stress. This could be explanation for different vulnerability of plants organs to cavitation. It was shown that in forest tree species that develop a low whole-plant hydraulic resistance such as Acer saccharinum (Tsuda and Tyre, 1997) or Junglans regia L. (Tyre et al., 1993) petioles would be more vulnerable than stems, and stems than roots. However, petioles of the strict riparian Betula occidentalis showed lower vulnerability to cavitation than stems, and stems were less vulnerable than roots (Sperry and Saliendra, 1994). On the other hand Cochard et al. (1992) reported no differences in vulnerability for three Quercus species examined. In addition, shedding of older leaves that contribute to water saving can be viewed
as a recycling program within plant, allowing the reallocation of nutrients stored in older leaves to the stem or younger leaves.

Woody plants are characterized by extensive secondary growth, which itself respond to drought. An efficient hydraulic system for transporting water from soil to leaves allows to control the hydration of aerial tissues. The movement of water according to a gradient water potential starts as water reaches root stele. At this point water moves through path of conduits overcoming the hydraulic resistance imposed to water flow by very narrow elements. In contrast to herbaceous plants trees grow very tall which results in increased length of hydraulic path. Consequently, there was observed decrease in leaf-specific hydraulic conductance. Moreover, it has been proposed that tree growth may be hydraulically limited as a result of decreased water potential through the path (Sperry et al., 2008). In order to increase the efficiency of xylem in water transporting, plants seem to change the diameter of conduits. It has been observed that diameter increased with branching order (Mayr et al., 2003), tree age (Corcurea et al., 2004), or tree height (Zach et al., 2010). However, drought can affect negatively the average diameter of xylem as a response that induces an unbalance between water requirement and flow, which may result in damaging plant tissues and death. The formation of smaller vessels under drought has been observed in stems of various tree species, such as Quercus sp and Populus sp (Arend and Fromm, 2007; Fonti et al., 2013). It was suggested that smaller vessels may be less susceptible to drought–induced xylem embolism and that they also contribute to the regulation of water flow under water-limiting growth conditions. It seems that hydraulic system is supposed to meet the compromise of conductance efficiency versus security against the loss of its functionality in response to stressful conditions. Kozlowski and Pallardy (2002) observed that diameter of xylem conduits, responsible for transport of water, and the thickness of their cells can be modified, resulting in increased resistance against cavitation in the vascular tissue. Nevertheless, essential difference in the vulnerability to xylem cavitation have been reported for a wide range of species, resulting that species which show higher tolerance to drought exhibit hydraulic system more resistant to cavitation (Maherali et al., 2004, Brodribb and Cochard, 2009). Recovery of xylem functionality after water stress also play crucial role in drought tolerance of forest tree species. This process may be mediated by development of new xylem or by restoring the function of previously embolized vessels (Brodribb et al., 2010).

Other important trait for understanding drought tolerance of tree species are hydraulic properties of leaves. When water arrives to leaves, it still flow through the xylem across their veins. Petioles and leaf veins consist of xylem tissue which cause that they are also vulnerable to cavitation if water flow to atmosphere is high enough to generate critical water potential drops. Since hydraulic of leaf lamina seems to have significant contribution in whole-plant resistance to water flow. The processes responsible for changes in leaf hydraulic such as molecular mechanisms involved in aquaporins gating in tissues of leaves need to be explained. The potential role of leaves in mechanism for preserving the integrity of other organs by limiting transpiration during water stress also need to be elucidated.

AQUAPORINS IN DROUGHT RESPONSE

Besides mechanisms to optimize water uptake, transport and control of loses under drought, trees have developed strategy to increase the tolerance to the dehydration of their tissues. Water transport in inner tree tissues is targeted by multiple regulation, which tend to stabilize the tree water status and provide for adaptation of tree for its environment. Regulation of root hydraulic conductivity and leaf hydraulics provide a means for drought stress avoidance and tolerance strategy. Recent research into mechanisms of tree response to water deficit on molecular level has indicated the role of aquaporins and have shown that this group of proteins can play key role in hydraulic regulation in roots and leaves during drought.
This review discusses the functions of aquaporin in water transport, particularly with respect to root hydraulic in response to water stress conditions.

Aquaporins are a family of channel proteins that are found in cellular membranes and are responsible for water flux and small neutral molecules transport thus play key roles in maintaining the water balance. In plants aquaporins occur as a multiple isoforms reflecting a high diversity of cellular localizations, transport selectivity, and regulation properties. Plant aquaporins are localized in plasma membrane, endoplasmic reticulum, vacuoles, plastids and, in some species, in membrane compartments interacting with symbiotic organisms. In contrast aquaporins seem to be excluded from such compartments as mitochondria and peroxisomes. Higher plant aquaporins can be grouped into five subfamilies: the plasma membrane intrinsic proteins (PIPs) and the tonoplast intrinsic proteins (TIPs) representing the largest subfamilies, the small basic intrinsic proteins (SIPs), the nodulin 26-like intrinsic protein (NIPs), the uncharacterized X intrinsic protein (XIPs).

Root water uptake and distribution is controlled by aquaporins activity (Almeida-Rodriguez et al., 2011). Water transport through the roots involve a combination of three pathways: the apoplastic path, the symplastic path and transcellular path. The transcellular water movement is tightly controlled by the amount and activity of aquaporins. There is a rapid exchange of water between parallel radial pathways because, in contrast to solutes such as nutrients ions, water permeates cell membranes readily. The apoplastic barriers consist of the Casparian bands and the suberin lamellae in exodermis and endodermis of roots. This two cell layer are characterized by formation apoplastic barriers, through lignin deposition at Casparian strips. Consequently whole apoplasm undergo suberization, which in result limit water transport. By switching the apoplastic path on or off, water uptake is regulated according to demand from shoots (Steudle, 2000). At high rates of transpiration, the apoplastic path way is partially used and the hydraulic resistance of roots is low and evenly distributed across the root cylinder, allowing for rapid uptake of water. On the contrary, at low rates of transpiration such as during drought conditions, the apoplastic pathway is used less. Instead, water flow is mainly transcellular, which causes a high hydraulic resistance as water passes across membranes via aquaporins in its passage across the root cylinder (Steudle, 2000). During condition of water deficit, the suberisation of roots minimizes water loss to the dry soil. Aquaporins then may act as valves to reversibly increase the hydraulic conductivity and allow for water uptake under drought conditions. It has been shown that aquaporins can be activated by phosphorylation, which is affected by water potential, turgor, or Ca\(^{2+}\) concentration in apoplast (Steudle, 2000).

Studies on testing the contribution of aquaporins to root water transport was conducted with using a aquaporins blockers in particular, mercury. It was shown that mercury inhibited root hydraulic conductivity (Maggio and Joly, 1995; Sutka et al., 2011). However, results indicate that the relative importance of aquaporin–dependent path can vary between plant species and participation of this path in respect to woody plants needs to be elucidated. Aquaporins expression patterns can also provide a useful information on the contribution of water channels to root water transport. Examination of aquaporin expression in roots have focus on PIPs which are supposed to play crucial role in plasma membrane and transcellular water transport, and TIPs, which show high expression level in roots. For instance, in poplar (Populus trichocarpa, Populus balsamifera, Populus simonii x balsamifera) a total of 56 aquaporins have been identified (Gupta and Sankararamakrishnan, 2009; Almeida-Rodriguez et al., 2010). In all species examined, very precise and distinct cell–specific expression patterns could be established for numerous aquaporins isoform presents in roots. Data emphasize the importance of controlling local hydraulic properties all along the radial pathway, with preferential expression of some isoform in two root tissues: exodermis or endodermis. Some other isoform were highly expressed in root stele, which is consistent with
centripetal transport of water toward the root, whereby water flows have to be mediated by reduces exchange surface. Recent studies indicate that aquaporin expression profile varies along the root axis. It shows that radial pathway can change during root growth and differentiation.

Direct exposure of roots to water stress usually result in inhibition of aquaporin activity and water transport at the cell and whole organs levels. On the other hand some plants shows opposite responses with an enhancement of root cell hydraulic conductivity. Almeida-Rodriguez conducted studies of the expression levels of aquaporins in roots using quantitative RT-PCR. Results showed that increase in root hydraulic conductance coincided to increases transcript abundance of 15 aquaporins out of a total 33 genes. Expression level for two PIPs, two TIPs increased two times while two other PIPs showed greater than two fold decrease. Studies with hybrid poplars which experienced a sudden drop in humidity showed that root water flow was tightly connected with aquaporin expression pattern (Laur and Hacke, 2013). Results from recent studies demonstrate that many physiological responses of plants to drought, avoidance as well tolerance responses, are mediated by plant hormone abscisic acid (ABA), although the underlying mechanisms are not fully understood yet (Munns and Cramer, 1996; Claeys and Inze, 2013). Abscisic acid is produced in roots and its level increase upon exposure to drought and is accompanied by changes in gene expression and physiological responses. Under drought conditions, ABA increases aquaporins expressions, which translates into increased hydraulic conductance. However, the effects of abscisic acid on root hydraulic conductivity also depend on time of observation and examined species. On the one hand ABA transiently enhances cell hydraulic conductivity in maize root cells, on the other hand it inhibits root hydraulic conductivity in aspen. These observation indicate that plants various hydraulic strategies in response to soil drying. Increase root hydraulic activity during the early phase of drought could help optimize the capture of soil water resources, a long term inhibition provides a more conservative mechanism for the plants, to prevent a reverse flow of water, from the plant root into dry soil.

CONCLUDING REMARKS

Wood quantity and quality utilized in forest industry is highly dependent on trees growth conditions. Water availability is among the most limiting factors for plant growth. Therefore, research into drought impact on tree growth and wood formation is becoming increasingly important, as the severity and frequency of drought are expected to increase (IPCC 2014). Great progress in the understanding plant strategies to control water status under drought and the physiological and biochemical processes underlying tree response to water deficit has been made recently. The discovery of aquaporins was a major breakthrough in the understanding of water flow through living plant cells. Aquaporins, channel proteins located in cellular membranes, mediate water flux, maintaining proper water balance. They can be found both in plasma membrane and in vacuole membrane, and their expression is induced by water deficit. Moreover, aquaporin also transport small molecules across biological membrane. Transport processes play important role in the mobilization and accumulation of solutes and hormones and in cell detoxification pathway during adaptation to water stress. Thus, aquaporins can be involved in the drought stress response. So far several works have focused on this protein family in forest tree species and on its role during drought stress recovery. Further studies are needed to elucidate possible functions in differential drought responses of forest tree species.
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Streszczenie: Udział akwaporyn obecnych w korzeniu w odpowiedzi drzew na stres wywołany suszą. Ilość i jakość drewna pozyskiwanego do wykorzystania w przemyśle drzewnym zależy w dużym stopniu od warunków wzrostu drzew. Dostępność wody jest jednym z czynników które najbardziej ograniczają wzrost drzew. Dlatego znaczna ilość badań naukowych koncentrowała się na zrozumieniu mechanizmów lezących u podstaw odporności drzew na suszę. Przewodnictwo hydrauliczne tkanek roślinnych odgrywa ważną rolę w reakcji na suszę. Transport wody z właściwołek korzeniowych do ksylemu może odbywać się jednocześnie trzema drogami: apoplastyczną, symplastyczną i transbłonową. Przemieszczanie się wody przez błony komór komórek tkank korzeniowych umożliwia akwaporyny. Akwaporyny to integralne białka błonowe, które tworzą kanały, uczestniczące w procesie transportu wody a także niektórych innych cząsteczek o podobnych rozmiarach przez półprzepuszczalne błony komórek organizmów żywych. Zróżnicowana ekspresja akwaporyn w tkankach roślinnych w warunkach fizjologicznych oraz w odpowiedzi na stres wywołany czynnikami abiotycznymi sugeruje, że mogą one pełnić istotną rolę w utrzymaniu równowagi wodnej w roślinach. W artykule omówiono potencjalną rolę akwaporyn w odpowiedzi drzew a w szczególności ich korzeni na stres wywołany suszą.

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Imaging of anode biofilm in cellulose-fed microbial fuel cell

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Abstract: Imaging of anode biofilm in cellulose-fed microbial fuel cell. In the present work a possibility of formation of anode biofilm in cellulose-fed microbial fuel cells inoculated with bacteria native to cattle manure has been investigated. The analysis with the use of scanning electron microscopy revealed that in the investigated conditions microorganisms create thick biofilm with expanded pilli network. The possible function of this network may be adhesive or electrogenic.

Keywords: microbial fuel cell, cellulose, anode biofilm

INTRODUCTION

The constant growth of population results in increasing demand for energy. According to International Panel on Climate Change (IPCC) global demand for energy will be doubled by 2095 to reach 1200 EJ per year (IPCC special Report on Carbon Dioxide Capture and Storage 2005). Therefore, an intensified research for renewable sources of energy is nowadays justified because nearly 95% of the consumed energy today comes from the fossil fuels. An obvious alternative for the depleting non-renewable resources is lignocellulosic biomass which can be converted to bioethanol (Yung et al. 2013), biobutanol (Qureshi et al. 2008), methane (Nievesa et al. 2011) or hydrogen (Wang et al. 2009) through fermentation. However, most of these methods require substrate pretreatment (e.g. saccharification) and auxiliaries, so that the gain coming from renewability of the raw materials is reduced by energy input during the process and yielded by-products (Rubín 2008). These features are limitations for implementation of this technique in green technology. Thus, a complementary, free of these limitations approach is needed. MFCs are the bioelectrochemical systems employing microorganisms able to directly convert chemical energy into electricity in the course of their metabolism. Due to exoelectrogenic activity of microorganisms, it is possible to oxidize substrates and release electrons. The released electrons are transferred to an anode of the fuel cell (Gregoire et al. 2012). The move of electrons from anode to cathode is responsible for current generation in the MFC system. A detailed MFC operation fundamentals have been discussed by Debabov (2008).

Cellulose is the most abundant polysaccharide in nature, therefore efforts have been undertaken to design efficient both electrochemical (Sugano et al. 2010) and bioelectrochemical (Ren et al. 2007, Rismani-Yazdi et al. 2007) fuel cells operating on cellulose as a substrate. In previous works the use of specialized isolated bacteria species like Enterobacter cloacae (Rezaei et al. 2009), Geopsychrobacter electrophilicus (Holmes et al. 2004), Shewanella putrefaciens (Kim et al. 1999, Kim et al. 2002) or Rhodopseudoonas palustris (Xing et al. 2008) are described. There are also reports on the cellulose-fed MFC where binary culture – i.e. fermentor - exoelectrogen was successfully exploited. The key factor determining usefulness of various microorganisms for current generation from cellulose in MFC system is the ability of biofilm formation on the anode resulting in current generation.
In this work the development of anode biofilm in cellulose-fed microbial fuel cell inoculated with bacteria native to cattle manure has been investigated.

MATERIAL AND METHODS

Microbial fuel cell construction and operation

In the present investigations two-chamber microbial fuel cells were used. 50 ml cathode and 50 ml anode chambers were separated by 2 cm × 0.7 cm agar bridge (10% agar, 10% NaCl) with 1 cm² graphite electrodes as described previously. The distance between electrodes was 3 cm. The anode solution (50 ml) was 25 ml of 50 mM phosphate buffer, 0.31 g/l NH₄Cl, 0.13 g/l KCl, 1% cellulose powder (Sigmacell, Sigma Aldrich, US) and 25 ml of cattle manure. The cellulose added to the anode chamber consisted of 85% crystalline cellulose and 15% amorphous cellulose and was directly added to the anolyte solution without any earlier pretreatment or solubilization. The catholyte solution (50 ml) included 100mM K₃Fe(CN)₆ in phosphate buffer (100mM). The anode chamber was sealed with rubber stopper. The cathode chamber was in contact with air. The MFC was connected with high impedance multimeter and worked under external resistance R=1000 Ω, as described previously (Toczyłowska-Mamińska et al. 2016).

Scanning electron microscope imaging of anode bacterial biofilm

The samples were analyzed on a 168 Zeiss Sigma VP SE2 SEM instrument. The preparation of the electrodes for the SEM imaging was made according to the procedure described in the previous study (Toczyłowska-Mamińska et al. 2015).

RESULTS

Bacterial communities capable to transfer electrons to the surface of anode are termed anodophiles (Rabaey et al. 2004). The transfer is realized after they form a biofilm onto the anode. In this tens of micrometers thick microbial system only some portion of bacterial community adhere directly to the anode, while upper layers of bacteria are connected with the others by the endogenous electron transporters called nanowires or nanopili. Numerous works regarding major groups of the bacterial community native to cattle manure can be found in the literature (Zhang et al. 2012, Rabaey et al. 2004, Zhao et al. 2012). The predominant identified phyla present in manure-based MFC are Firmicutes, Proteobacteria, Bacteroidetes, Chloroflexi and Actinobacteria. However, only few of them are documented as exoelectrogenic. The ability of bacteria native to cattle manure to form a biofilm was investigated with the use of SEM microscopy. The micrographs were made after 30 days of MFC operation under external resistance resulting in current production. The micrographs revealed thick bacteria layer at the electrode surface in comparison with plain graphite electrode (Fig.1). An exuberant pilli network which is very characteristic and usually assigned to the electrogenic strains. However, pilli may play various functions in bacteria, including locomotion, adherence, DNA uptake, protein secretion and also can act as nanowires transferring electrons to the electrode (Aas et al. 2002, Mattick 2002, Han et al. 2007). Among bacteria identified previously in cattle dung operating MFCs, the most often found are Firmicutes. Among Firmicutes, Clostridium species were widely reported to produce pilli (Melville et al. 2013).
Though, it is not known what is the function of the observed network, especially if it is connected with electron transferring.

Fig. 1. Scanning electron micrographs of (A) graphite electrode and (B) biofilm formed onto graphite anode after 30 days of MFC operation.

SUMMARY

In this work it has been shown that bacteria native to cattle manure develop anode biofilm in MFC system when cellulose is used as a substrate. The imaged biofilm is characterized by the exuberant pilli network covering whole anode surface. The function of this network may be connected with adherence of microorganisms to the electrode surface or with transfer electrons to the anode.

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Streszczenie: Wizualizacja biofilmu anodowego w mikrobiologicznym ogniwie paliwowym zasilanym celulozą. W niniejszej pracy zbadano możliwość utworzenia biofilmu na anodzie w mikrobiologicznym ogniwie paliwowym zasilanym celulozą, w którym zastosowano bakterie pochodzące z treści jelitowej bydła. Zdjęcia wykonane z użyciem skaningowego mikroskopu elektronowego pozwoliły na potwierdzenie, że w badanych warunkach mikroorganizmy tworzą grubą warstwę biofilmu na anodzie, z charakterystyczną rozbudowaną siecią włoskowatych wypustek (tzw. pili). Funkcje obserwowanej sieci wypustek mogą być związane z adhezją bakterii do podłoża elektrody bądź z transportem elektronów do anody.

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Fire resistance tests of loadbearing walls of timber framework with linings of gypsum plasterboards

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Abstract: Fire resistance tests of loadbearing walls of timber framework with linings of gypsum plasterboards. The results of two fire resistance tests of the loadbearing walls with timber framework with linings of gypsum plasterboards are presented and discussed. One wall was tested under standard fire exposure. Second wall was tested under external fire exposure. The walls had different construction, in particular on the exposed side. Also level of load applied to the wall was different. Big difference in the behavior of the walls was recorded. First wall, even under almost 3 times less loading, collapsed after 45 minutes of the test. The second one did not exceed any of the fire resistance criteria during 132 minutes of the test. It seems that the load redistribution played more substantial role in the first wall behavior than the damage of the studs due to the timber charring.

Keywords: fire resistance test, timber structure, wall, gypsum plasterboards

INTRODUCTION

In Europe and worldwide more and more modular construction work with use of timber framed walls constructed from softwood elements and lining of gypsum plasterboards are built. Modular building of general use like schools, kindergartens, libraries or residential buildings may have several floors. Walls of such buildings, due to the regulations and technical prescriptions, must fulfill fire resistance requirements from REI 30 up to REI 120. Walls constructed of timber framework with linings of gypsum plasterboards are able to obtained such classifications depending on the construction, level of loading and envisaged fire resistance class.

1. LOADBEARING WALLS – FIRE RESISTANCE TEST STANDARDS AND CRITERIA

The testing procedure for loadbearing walls is defined in the standard EN 1365-1 [1]. Regarding testing conditions and criteria it refers to two other standards: EN 1363-1 [2] (dealing with general requirements) and EN 1363-2 [3] (concerning additional and alternative procedures). Classification procedure is described in EN 13501-2 [4].

Test specimen shall be loaded with a load determined in accordance with EN 1363-1 [2]. The value and distribution of load shall be such that internal forces developed in test specimen shall be representative for real situation.

The testing element having minimum dimensions of: width ($W_{\text{exp}}$) – 3 m, height ($H_{\text{exp}}$) – 3 m, shall be exposed to defined thermal exposure (fire action) during fire resistance test. In case of external walls two scenarios are considered:

- fire from inside – defined by standard time/temperature curve (N),
- fire form outside – defined by external fire exposure curve (E).

Standard time/temperature curve is defined as follows:

$$ T = 345 \cdot \log_{10}(8t + 1) + 20 \quad (1) $$

External fire exposure curve is defined as follows:

$$ T = 660 \cdot [1 - 0,687 \cdot e^{-0,32t} - 0,313 \cdot e^{-3,8t}] + 20 \quad (2) $$

where:
$T$ – is average temperature in the furnace, in Celsius degrees, $t$ – is time, in minutes.

The both time/temperature curves are illustrated in Fig. 1.

**Figure 1.** Heating curves for external loadbearing walls (fire actions)

The pressure of gasses in the furnace measured at the level of top edge of the test specimen shall not exceed 20 Pa, within tolerances given in the standard EN 1363-1 [2].

Fire resistance criteria for loadbearing walls with fire separation function are defined as follows:

**Loadbearing (R):**

a) axial contraction $C = h/100$ (mm) and  
b) rate of axial contraction $dC/dt = 3h/1 000$ (mm/min) 
where $h$ is the initial wall height in mm.

**Integrity (E):** The assessment of integrity shall be made on the basis of the following three aspects:

a) cracks or opening in excess of given dimensions;  
b) ignition of a cotton pad;  
c) sustained flaming on the unexposed side.

**Insulation (I):** The performance level used to define thermal insulation shall be the mean temperature rise on the unexposed face, limited to 140 °C above the initial mean temperature, with the maximum temperature rise at any point limited to 180 °C above the initial mean temperature.

2. CONSTRUCTION OF TESTED LOADBEARING WALLS

Two fire resistance tests were carried out on external loadbearing walls: one under standard fire exposure and one under external fire exposure. Both walls had the same height and both were loaded during the tests. Difference in loading level was an effect of the differences in timber studs sections.

3.1. CONSTRUCTION OF THE WALL TESTED UNDER STANDARD FIRE EXPOSURE

The loadbearing wall dimensions of 3.0 x 3.0 m had framework of timber studs of structural finger jointed solid timber softwood according to PN-EN 15497:2014-06 [5] section of 38 x 140 mm in 600 mm spacing. Timber was class C24 of measured humidity 12%. Studs were fixed to the ground beam and head binder by means of nails. One layer of gypsum plasterboards was fixed on both sides to the timber framework by means of steel staples. The
space between the studs was filled in with glass mineral wool. The wall had symmetrical construction. Both vertical edges were left unfixed. The load of 32 kN/m was applied to the top edge of the wall.

During the test unexposed surface temperatures, temperatures in the wall section, vertical deflections and horizontal deflections were measured.

3.2. CONSTRUCTION OF THE WALL TESTED UNDER EXTERNAL FIRE EXPOSURE

The loadbearing wall dimensions of 3.0 x 3.0 m had framework of timber studs of structural finger jointed solid timber softwood according to PN-EN 15497:2014-06 [5] section of 45 x 120 mm in 600 mm spacing. Timber was class C24 of measured humidity 12%. Studs were fixed to the ground beam and head binder by means of nails. The space between the studs was filled in with glass mineral wool. Two layers of gypsum plasterboards were fixed on one side of the wall to the timber framework by means of steel staples. On the other side of the wall one layer of gypsum plasterboards was fixed to the timber framework by means of steel staples and next external thermal insulation composite system (ETICS) with mineral wool thickness of 120 mm as insulation layer was applied. The external surface was finished with silicone plaster. The wall had asymmetrical construction. The wall was heated from ETICS side. Both vertical edges were left unfixed. The load of 60 kN/m was applied to the top edge of the wall.

During the test unexposed surface temperatures, temperatures in the wall section, vertical deflections and horizontal deflections were measured.

4. TEST RESULTS AND DISCUSSION

4.1. WALL TESTED UNDER STANDARD FIRE CONDITIONS

The view of the wall in the furnace prior to the test is shown in Fig. 2.

![Figure 2. View of the tested wall prior to the test](image_url)

The wall collapsed in 45 minute 58 seconds.
The view of the test specimen during the test at the moment of the wall collapse is shown in Fig. 3.

![Figure 3. View of the tested wall at the moment of the wall collapse](image)

The temperature rises in wall section along the studs depth (behind the board on exposed side, in the middle, behind the board on unexposed side), vertical deflections of the wall and horizontal deflections of the wall (appropriately scaled) are presented in Fig. 4.

![Figure 4. Temperatures in the wall studs and deflections of the wall](image)

TE17, TE20 – temperatures from the exposed side,  
TE18, TE21 – temperatures in the middle of the stud depth,  
TE19, TE22 – temperatures from the unexposed side,  
LD15, LD16, LD17 – vertical deflections,  
L2, L3, L4 – horizontal deflections.
The test results show that there is no direct correlation between recorded temperatures and deflections. The temperature 300 °C, characterizing timber charring, was exceeded in 27th minute (TE17 – third stud from the left in view from unexposed side) and in 23rd minute (TE20 – fourth stud from the left in view from unexposed side) at the stud ends on the exposed side. In the middle of the studs depth the temperature 300 °C was exceeded in 37th minute (TE21 – fourth stud from the left in view from unexposed side); temperature on the third stud from the left in view from unexposed side did not reach 300 °C till the test termination. Of course this temperature change has nothing to do with timber charring. These measurements were done at the stud surface so measured was the surrounding air temperature. Assuming that the temperature of 300 °C was reached in left stud at 27th minute and taking maximum charring rate of 0.8 mm/min (as for solid timber including the effect of corner roundings and fissures), it can be calculated that at 45th minute the theoretical depth of the stud decreased to 125.6 mm what is almost 90% of the stud depth. Even so, after less than 1 minute, the collapse of the wall occurred. The calculations are not very much accurate, but give the general picture of the situation. It is more likely that the load redistribution had substantial influence on the wall behavior.

4.2. WALL TESTED UNDER EXTERNAL FIRE CONDITIONS

The test lasted 132 minutes. During the whole test duration any of the fire resistance criteria were exceeded.

The load level during that test was almost 2 times higher than in the first test described above, but the fire action was substantially less severe than in that first test.

The temperature rises in wall section between the mineral wool insulation and gypsum plasterboards on exposed side and along the studs depth (behind the board on exposed side, in the middle of the studs depth, behind the board on unexposed side) are presented in Fig. 5.

![Figure 5. Temperature rises in the section of the wall](image)

| TE19, TE23 | temperatures between mineral wool insulation and gypsum plasterboards on the exposed side, |
| TE20, TE24 | temperatures along the wall studs from the exposed side, |
| TE21, TE25 | temperatures along the wall studs in the middle of the studs depth, |
| TE22, TE26 | temperatures along the wall studs from the unexposed side. |

Measured vertical deflections were less than 2 mm. Measured horizontal deflections were less than 5 mm.
The test results show that during the test there was no any substantial effects of heating and loading of the wall. Unexposed surface temperature rise did not exceed 35 °C. The temperature rises in the section of the wall along studs depth did not reach 140 °C. The deflections of the wall, both vertical and horizontal, can be recorded as negligible.

5. CONCLUSIONS

- The external walls of timber construction with linings of gypsum plasterboards can be used as loadbearing walls in different fire resistance classes.
- For such constructions with non-combustible insulation layer the more severe is standard fire exposure from inside.
- Walls with combustible insulation layer need to be tested with fire exposure from each side.
- On the basis of the tests carried out it is impossible to link behavior of the tested wall with charring of the timber framework. It seems that the more influencing is the load distribution during the fire resistance test.
- Walls of timber framework with gypsum plasterboard linings can be classified as loadbearing elements with fire separation function under standard fire exposure in different fire resistance classes, in accordance with EN 13501-2 [4], e.g. REI 30 (i→o), REI 60 (i→o) depending on the section of timber construction elements, gypsum plasterboard linings and level of loading.
- Fire resistance class of walls of timber framework with gypsum plasterboard linings under external fire exposure depends very much on the external insulation layers; such walls can be classified as loadbearing elements with fire separation function in different fire resistance classes, in accordance with EN 13501-2 [4], e.g.: REI 30 (o→i), REI 60 (o→i), REI 90 (o→i), REI 120 (o→i).

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Polish wood industry and its economic importance. Part 1

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Abstract: Polish wood industry and its economic importance. Part 1. Attempting to assess the chances of polish wood-industry companies on EU markets it is worth to analyse values and indexes characterising them - the companies - in the first place. In this article, we will start by probing the numbers of wood industry companies and quantity of wood processed. The analysis shows that fragmentation is characteristic to polish wood-industry. Highest quantities of processed wood are noted in case of biggest companies - only few of them exist in the market. Small companies, represent 60% of all businesses in the field of wood processing. They process less then 1000m³ of wood annually and have low share in total quantity of processed wood in Poland.

Keywords: wood-industry companies, wood process, competitiveness.

INTRODUCTION

Wood-industry sector in Poland consists of sawmill industry, wood based panel industry and furniture industry. Each of these components is growing gradually and introduces new investments such as new LVL factory in Czarna Woda announced by FORTE. Technical and technological level of wood based panel industry and furniture industry does not differ from the European industries. Differences can be observed in Polish sawmill industry – the technical level of Polish sawmill is lower then the average European level. The basic problem of Polish sawmill industry is its quantitative structure – a large number of very small mills in Poland – and the lack of capital for investment. In Poland there are a lot of small sawmills that are not able to make significant investments. Despite these obstacles sawmill industry in Poland has been systematically modernized. The modernization process was initiated many years ago by the biggest sawmills, for example Tartak Olczyk, KPPD, Barlinek, Stelmet or Poltarex. Currently, building of new big factory of Stelmet – “Mr Garden” in Grudziądz continues. Except that, the small but well-managed family businesses are being modernized. A good example of this trend are “Tartak Janina i Wacław Witkowscy” and “Więzary Burkietowicz”. At the same time, next to the sawmills derived from domestic capital, arise sawmills owned by foreign capital, such like IKEA (sawmills in Wielbark, Koszki, Stalowa Wola) and Stora Enso (sawmill in Murów). The sawmill industry also suffers from deficit of timber in Polish market, while the amount of wood harvested from the Lasy Państwowe is constantly growing. In 2015 in Poland were acquired 38327000 m³ of roundwood with diameter greater than 7cm on the thinner end, 1406000 m³ of that number in private forests (according to Raport o Stanie Lasów w Polsce, 2015). In 2017 Lasy Państwowe is planning to produce 40,5 millions m³ of roundwood. The number of entities purchasing roundwood from the Lasy Państwowe in 2016 year was equal to 7406 (Balaun, 2016). Despite many difficulties encountered by the sawmill industry, it is constantly growing and its role in Polish economy constantly increasing. The first stage of analysis of the economic importance of the wood-industry sector for the Polish economy, the authors began by analyzing the quantity structure and size exclusion woodworking plants and the amount of raw material purchases in
the Lasy Państwowe.

RESULTS

Analyzing the Polish wood market you can conclude, that it is characterized by high fragmentation. The structure of wood processing enterprises in terms of the amount of wood processed per year in Poland is shown on Figure 1.

![Figure 1. The structure of the wood-industry companies in Poland in 2013 due to the amount of wood processed per year (in cubic meters)](image)

The largest share - about 60% of market - have companies that process up to 1000m³ of wood per year. Large companies, that process over 100000m³ of wood per year represent only 0.43% of all wood processing enterprises in Poland, and economic statistics from 2013 indicate, that the largest - that process over 1mln m³ of wood per year - are only 3 of them - therefore they represent 0.04% of all wood processing entities included in statistics. Such data could mistakenly lead to the conclusion, that the most important role in Poland belongs to entities that process up to 1000m³ of wood per year – 4683 entities in 2013, according to statistics. Of course, the importance of these companies to the economy can not be overemphasized. We should, however, pay attention to the total annual volume of processed wood in these units, presented in Figure 2.
According to the analysis of the data shown in the Figure 2, the smallest entities of the wood industry process only 5.22% of the total processed amount of wood (exactly 1636843 m$^3$). Larger share of the total amount of wood processed reached companies, that process up to 5000 m$^3$ of wood per year, which represent approximately 30% of all wood processing enterprises in Poland. Total amount of wood processed in that companies reaches almost 5.26mln m$^3$, which represents about 16.8% of production of all analyzed companies. However, highest amount of processed wood is listed by the few big and largest enterprises, which constitute small amount at the Polish market (respectively 0.43% and 0.04%). Quantities of wood processed in that companies reaches 13,35mln m$^3$ per year (which, for these groups of companies, represents around 30.8% and 11.7% market share of wood processing). Therefore, it can be seen, that the total amount of wood processed by the two most numerous groups of enterprises represent approx. 22% of wood processing market, while two smaller groups of companies make almost twice as much (over 42% share of wood processing market).

Market analysts emphasized the importance of an added value. It is defined as output minus intermediate consumption. The Figure 3 shows the share of wood-industry companies in developing added value of domestic industry.
Figure 3 analysis leads to the conclusion, that added value developed by the wood industry is steadily increasing. The highest indications of added value are observed in the manufacture of paper and paper products, which compared to 2005 recorded an increase of approximately 19%, and the furniture industry, which in the same period recorded an increase of added value by almost 11%. Only manufacture of products of wood, cork, straw and wicker shows in 2014 a 0.18% decrease of added value in relation to 2005.

Figure 4 shows share of wood-industry companies in developing value added in industrial processing.
As for the individual sectors that make up the wood industry, their share in the value-added of industrial processing are stable in recent years and in the last analyzed year reach 11.34%. The share of value added for the manufacture of products of wood, cork, straw and wicker reached 3.64% of the value achieved by the industrial processing; the share of value-added for manufacture of paper and paper products reached 3.43%, while the added value of furniture manufacture reached 4.28% of total industrial processing.

Another characteristic of a Polish wood industry is the export of its products. Table 1 summarizes the data on wood-industry companies export on the background of industrial manufacturing and industry in general and the value and dynamics of exports for the main directions.

<table>
<thead>
<tr>
<th></th>
<th>Total (in mln zl)</th>
<th>To Developed countries (in mln zl)</th>
<th>To Countries of Central and Eastern Europe (in mln zl)</th>
<th>To Developing countries (in mln zl)</th>
</tr>
</thead>
<tbody>
<tr>
<td>T O T A L</td>
<td>440337</td>
<td>457521.1</td>
<td>3.90%</td>
<td>370352</td>
</tr>
<tr>
<td>Manufacturing</td>
<td>418829</td>
<td>437246.7</td>
<td>4.40%</td>
<td>352714</td>
</tr>
<tr>
<td>Manufacture of products of wood, cork, straw and wicker</td>
<td>10392.6</td>
<td>10252.9</td>
<td>-1.34%</td>
<td>9358.1</td>
</tr>
<tr>
<td>Manufacture of paper and paper products</td>
<td>11655.8</td>
<td>12170.2</td>
<td>4.15%</td>
<td>9056.5</td>
</tr>
<tr>
<td>Manufacture of furniture</td>
<td>18397.7</td>
<td>21336.5</td>
<td>15.97%</td>
<td>17248.5</td>
</tr>
</tbody>
</table>

Participation of Polish wood industry in the export of industry in general represents a little over 9.5%, while in industrial manufacturing 10%. The highest growth rate of export is achieved by the manufacture of furniture (an increase of about 16% compared to 2013). Decline in exports in relation to 2013 year is observed for the manufacture of products of wood, cork, straw and wicker (-1.34%). The furniture manufacturing companies export most of their products to the developed countries, including the European Union (one of the most important markets for Polish furniture for years is the German market). The dynamics of the export in this sector in 2014 reached almost 17%. A slight increase in exports year-to-year in the analyzed market is also listed by the national sector of manufacture of products of wood, cork, straw and wicker. The highest values of exports to developing countries again are observed in the case of Polish furniture manufacturing (approx. 11%); Polish producers of paper exported against 2013 1.49% more of its products, while the manufacture of products of wood, cork, straw and wicker again recorded a decline in exports to developing countries (-5.85%). Interesting is the export of Polish wood industry products to the countries of Central and Eastern Europe. As shown by the GUS data, all the analyzed sectors of native wood industry recorded a decline in exports of their products on this market (the highest decrease noted by manufacture of products of wood, cork, straw and wicker and manufacture of paper and paper products).

CONCLUSIONS

Polish wood industry is an important sector of the economy in the country, and the data allows to note, that it is constantly evolving. In 2014 wood-industry companies generated approx. 8.5% of the added value of the entire domestic industry. Important is the fact, that the share of this industry sector in the added value earned by total industry has been growing. In
the monetary values, the sector's share in the value added of the Polish economy gradually increasing, almost doubling its value: from almost 17 billion PLN in 2005, to 32 billion PLN in 2014. The fastest developing sectors in wood industry are manufacture of paper and paper products and furniture manufacture, the weakest results recorded timber industry. It can be easily noticed, that the added value of industry developed in 2014 by the manufacture of products of wood, cork, straw and wicker reaches a level lower than recorded in the year after the Polish accession to the European Union.

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Polish wood industry and its economic importance. Part 2

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Abstract: Polish wood industry and its economic importance. Part 2. Attempting to assess the chances of polish wood-industry companies on EU markets it is worth to analyse values and indexes characterising them - the companies - in the first place. Besides probing numbers of companies, very important data can be retrieved from analysing value and dynamics of sales of polish wood industry companies. From 2005 to 2014 one can observe increase of value of sold production. This increase can be seen in all sectors of wood industry.

Keywords: wood-industry companies, wood process, competitiveness.

INTRODUCTION

Wood-industry sector in Poland consists of sawmill industry, wood based panel industry and furniture industry. Each of these components is growing gradually and introduces new investments such as new LVL factory in Czarna Woda announced by FORTE. Technical and technological level of wood based panel industry and furniture industry does not differ from the European industries. Differences can be observed in Polish sawmill industry – the technical level of Polish sawmill is lower then the average European level. The basic problem of Polish sawmill industry is its quantitative structure – a large number of very small mills in Poland – and the lack of capital for investment. In Poland there are a lot of small sawmills that are not able to make significant investments. Despite these obstacles sawmill industry in Poland has been systematically modernized. The modernization process was initiated many years ago by the biggest sawmills, for example Tartak Olczyk, KPPD, Barlinek, Stelemt or Poltarex. Currently, building of new big factory of Stelmet – “Mr Garden” in Grudziądz continues. Except that, the small but well-managed family businesses are being modernized. A good example of this trend are “Tartak Janina i Waclaw Witkowski” and “Wiazary Burkietowicz”. At the same time, next to the sawmills derived from domestic capital, arise sawmills owned by foreign capital, such like IKEA (sawmills in Wielbark, Koszki, Stalowa Wola) and Stora Enso (sawmill in Murow). The sawmill industry also suffers from deficit of timber in Polish market, while the amount of wood harvested from the Lasy Państwowe is constantly growing. In 2015 in Poland were acquired 38327000 m³ of roundwood with diameter greater than 7cm on the thinner end, 1406000 m³ of that number in private forests (according to Raport o Stanie Lasów w Polsce, 2015). In 2017 Lasy Państwowe is planning to produce 40,5 millions m³ of roundwood. The number of entities purchasing roundwood from the Lasy Państwowe in 2016 year was equal to 7406 (Balaun, 2016). Despite many difficulties encountered by the sawmill industry, it is constantly growing and its role in Polish economy constantly increasing. In the second stage of the analysis of wood-industry sector economic importance for the Polish economy, the authors analyzed the value of sold production of wood-industry sector and the value of exports of its products, as well as the export of roundwood in the years between 2005 and 2014.
RESULTS

While assessing the economic importance of Polish wood industry, it is worth to analyse the value and dynamics of sold production. The corresponding data were shown in the Figure 1.

![Figure 1](image)

**Figure 1.** Values of sold production of the Polish wood-industry companies in years 2005-2014 (in mln PLN)

Sold production concerns the total economic activity of the company and mainly includes the value of sold products, semi-finished products and parts of own production and the value of services provided for a fee. As the Figure 1 shows, the value of sold production of wood industry in the years 2005 - 2014 increased steadily. In 2014, the value of sold production of the entire wood industry has increased compared to 2005 by slightly more than 75% to give a result close to the industry as a whole. Growth of sold production were observed for all sectors of wood industry, namely: manufacture of furniture (growth compared to 2005 by 63.03%), manufacture of products of wood, cork, straw and wicker (an increase of 67.51% ) and manufacture of paper and paper products (almost 100% increase compared to 2005).

The sold production of the wood industry, compared to the entire economy reached 8.51% in 2005, and in 2014 has slightly decreased (8.47%). These data were shown in Figure 2.

The Figure 2 analysis shows, that the largest decline of dynamics of sold production of wood industry was recorded in 2010. Starting that year, the value of sold production of the wood industry have been improving. Individual sectors in 2014 reached the following shares in the sold production of the wood sector: manufacture of products of wood, cork, straw and wicker – 2.79%, manufacture of paper - 2.77%, manufacture of furniture - 2.92%. The share of individual sectors in the aggregate value of wood industry sold production is therefore similar throughout analysed period and fluctuates around 3%. 

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Interesting are indications of the dynamics of production sold by these components of the timber industry. The indicators of the dynamics of sold production of sectors of the wood industry also look interesting. It turns out that the largest declines in sold production in 2014 compared to 2005 were recorded by manufacture of furniture (7.33%) and the manufacture of products of wood, cork, straw and plaiting materials (-4.78%). Only the paper production industry has recorded increase in sales compared to 2005 by 13.65%.

Significant impact on the important results and economic condition of the wood-industry companies has export and import. Export related data on selected wood products are presented graphically in Figure 3.

Presented on Figure 3 data, concerned on the share of exports of selected products of the wood-industry sectors in total Polish exports indicate, that although the value of export of wood-industry (products of Polish timber sector and various kinds of wood-based panels) since 2009 year-on-year increases, which confirms the gradual development of the industry, their share in total exports showed a downward trend in all analyzed period. Within 10 years, the share of sawn and planed wood fell from 0.27 to 0.12%; the share of wood-based panels fell from 0.27 to 0.09%, the share of hardboard declined from 0.40 to 0.28%, the share of the sheets of veneer and plywood fell from 0.06 to 0.02%, and the share of plywood and veneered panels fell from 0.16 to 0.08%. At the same time highly increased export of Polish roundwood, as can be seen in the Figure 3.

Selected destinations of wood export from Poland were shown in Figure 4.
Figure 3. Share of export of selected Polish wood industry products in entire industry in years 2004-2014

Figure 4. Selected destinations of wood export from Poland
Figure 4 shows a significant increase in exports of raw wood from Poland to the presented countries, especially since 2009, when auctions were introduced in the Polish wood market. This shows that the liberalization of the market allows for very fast and uncontrolled purchase of Polish wood by European Union countries. In the case of Germany, the Czech Republic and Lithuania in 10 years export of wood from Poland increased more than thirty times, and since 2009 respectively over six, four and eleven times. The largest absolute value growth of wood exports from Poland was recorded in Germany and the Czech Republic.

CONCLUSIONS

Wood industry is an important sector of the economy of Poland. Shown values characterizing it allow to note, that despite some difficulties, this sector is constantly developing. Analysis of value of sold production leads to the conclusion that, compared of total industry, discussed value of products generated by the wood-industry companies grows steadily. Detailed analysis of the dynamics of sold production of wood-industry sectors, however, provides information about declines in the furniture and wood manufacturing. Only the manufacturing of paper recorded growth of sold production against of sold production of entire wood industry compared to 2005. Also, the value of export of products of Polish timber and wood-based panels sectors increases from 2009, but the analysis of the share of exports in total exports showed a downward trend. A worrying phenomenon is the increase in exports of wood from 2009, especially to Germany and the Czech Republic, which can be the result of inadequate control of the market of round wood sales in the auction system. Also it indicates increase of exports of low processed products which indicates low developed economy.

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wchodzących w skład przemysłu drzewnego.

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Resistance of selected wood-based materials glued with nano-SiO$_2$/UF resin to *A. niger* infestation

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Abstract: Resistance of selected wood-based materials glued with nano-SiO$_2$/UF resin to *A. niger* infestation The aim of the study was to investigate the resistance of particleboards and plywood glued with nano-SiO$_2$ urea-formaldehyde resin (UF) to *Aspergillus niger*. Mycological tests were performed as described in EN-ISO 846 standard by visual inspection of the fungus presence on the surface of the boards after 5, 10, 14, and 21 days of incubation. The study demonstrated that particleboard was more resistant to *A. niger* attack than plywood. The most resistant were the samples of particleboard glued with nano-SiO$_2$/UF at the ratio of 2 parts by weight (pbw) of nano-SiO$_2$ per 100 parts by weight of the resin. Supplementation of the resin with nano-SiO$_2$ significantly reduced and slowed the development of fungal spores on the board surface. The plywood samples lacked any resistance to the fungus, irrespective of the filling (starch or nano-SiO$_2$) used for gluing the sheets of veneer.

Keywords: particleboards, plywood, UF resin, nano-SiO$_2$

INTRODUCTION

Nanoparticles and nanomaterials are gaining popularity in various industries. Their benefits have been recognized in the production of paints and lacquers and plastic materials (Sadhan and Sachin 2001, Royall and Donald 2002, Sow et al. 2011, Azinfar and Ramazani 2013). Possibilities of their application in the manufacture of wood-based materials have also been explored. The studies performed so far identified nanosilica as an effective compound for this purpose. It may serve as a nanofiller for the resins used in gluing veneer sheets during plywood production or as an additive enhancing mechanical strength properties of particleboards (Roumeli et al. 2012, Dukarska 2013, Dukarska and Derkowski 2014, Dukarska and Czarencki 2016). Considering the fact that an addition of nanoparticles to polymer compositions improves their barrier properties and that starch fillers commonly used for plywood production are not resistant to fungi (Proszyk 1990), a study was undertaken to evaluate the effect of adhesive supplementation with nano-SiO$_2$ on mycological resistance of wood-based materials glued with them. Therefore, the aim of this study was to determine susceptibility of particleboards and plywood glued with urea-formaldehyde resin supplemented with nano-SiO$_2$ to *Aspergillus niger* attack.

MATERIALS

The study involved two types of laboratory-manufactured wood-based materials, i.e. single-layer 12 mm thick particleboards of a density 700 kg/m$^3$ and triple-layer 4.5 mm thick plywood. The particleboards were produced in a laboratory at the following pressing conditions: temperature 200 °C, time 23 s/mm of board thickness and pressure of 2.5 N/mm$^2$. The boards were glued with 12% of urea-formaldehyde resin (UF). The samples were prepared either with or without nano-SiO$_2$. In those supplemented with nano-SiO$_2$ its ratio was two parts per weight (pbw) per 100 parts per weight of UF resin. The experimental plywood samples were finished with birch veneers of 6% moisture content and the thickness of individual layers was 1.4 mm, 1.7 mm, and 1.4 mm. Similarly as for particleboards, two
variants of plywood samples were manufactured. They were glued with the same urea-formaldehyde resins but with two different fillers, i.e. rye flour at 13 pbw/100 pbw of UF resin or nano-SiO$_2$ at 2 pbw/100 pbw of UF resin.

Nanosilica used in the study was hydrophilic fumed silica Orisil 200, a detailed description of which was published by Dukarska and Czarnecki (2016).

Both types of plywood were manufactured at the same conditions with the following pressing parameters: temperature 125 °C, time 4 min, pressure 1.4 N/mm$^2$. Application of adhesive mixture on the veneer sheets was 160 kg/m$^2$. At the next stage of the research, the produced samples were subjected to mycological tests that involved a visual inspection of their surface for the presence of mildew fungus $A. niger$ as per EN ISO 846 standard. For this purpose, 30 × 30 mm samples of particleboards and plywood were placed in sterile conditions on sterile Petri dishes filled with agar medium infected with aqueous solution of $A. niger$ spores. Then, the samples were incubated in an oven at 28 °C and air humidity of 95%. The assessment of mycelium growth on the medium was performed after 5, 10, 14, and 21 days of incubation according to the scale presented in Table 1. The control included samples of pine ($Pinus sylvestris$ L.) sapwood.

**Table 1** Macroscopic scale used for the evaluation of sensitivity of wood based material samples to fungal infestation

<table>
<thead>
<tr>
<th>Index</th>
<th>Degree of sample colonisation</th>
</tr>
</thead>
<tbody>
<tr>
<td>0</td>
<td>100% of the sample surface colonised by the test fungus mycelium</td>
</tr>
<tr>
<td>1</td>
<td>More than 15% of the sample surface colonised by the test fungus mycelium</td>
</tr>
<tr>
<td>2</td>
<td>Less than 15% of the sample surface colonised by the test fungus mycelium</td>
</tr>
<tr>
<td>3</td>
<td>No signs of mycelium growth on the sample</td>
</tr>
</tbody>
</table>

**RESULTS**

The resistance of particleboards and plywood glued with UF resin supplemented with nano-SiO$_2$ to $A. niger$ infestation is presented in Figures 1 and 2. These figures represent average degree of the sample surface coverage with the fungus after various incubation periods. They demonstrate that particleboards glued with UF resin with or without nano-SiO$_2$ were free from the mildew colonisation after 5 days of incubation (degree 3), while the control samples made of pine wood were colonised in 15% (degrees 1 and 2). The colonisation index of the control samples confirmed optimum conditions for the mycological test. After 10 and 14 days of the incubation, the surface of both particleboard samples was colonised to the same degree, i.e. above 15%, and the control samples were fully covered with the mildew. A difference between the particleboards became apparent only after 21 days of incubation. The samples of particleboard glued with pure UF resin were fully covered with mycelium, while those glued with nano-SiO$_2$/ UF still showed the same degree of colonisation (1). Figure 2 shows $A. niger$ colonisation of the plywood glued with UF resin supplemented with rye flour commonly used as a filler in plywood industry and of the plywood glued with nano-SiO$_2$/UF. The mycological assessment indicated that mean colonisation of both types of plywood was higher than for the control samples, the surface of which after five days of incubation was covered with the mildew in less than 15%.
The plywood glued with UF resin supplemented with nano-SiO₂ was fully covered with the mildew after only five days of the incubation, when the plywood glued with resin enriched with standard starch filler showed colonisation degree above 15%. Further readings were identical for both types of plywood and showed 100% colonisation with A. niger mycelium.

CONCLUSIONS

The mycological test showed that the particleboard glued with UF resin was a more resistant wood-based material than pine wood or plywood glued with the same resin supplemented with rye flour of nano-SiO₂ as fillers. After five days of incubation none of the particleboard samples were infested with A. niger. First differences appeared only after 14 days of the experiment. Supplementation of UF resin with nano-SiO₂ at 2 pbw/100 pbw of the resin markedly reduced and slowed the development of fungal spores of particleboard surface. Contrary results of mycological resistance were obtained for plywood samples. Irrespective of the filler, both investigated types of plywood showed no resistance to A. niger.
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**Streszczenie:** Odporność wybranych tworzyw drzewnych zaklejonych żywicą nano-SiO\textsubscript{2}/UF na działanie *A. niger*. Celem badań było poznanie odporności płyt wiórowych i sklejek zaklejanych żywicą mocznikowo-formaldehydową (UF) z dodatkiem nano-SiO\textsubscript{2} na działanie grzyba *Aspergillus niger*. Testy mikologiczne badanych tworzyw wykonano zgodnie z normą EN-ISO 846 poprzez wizualną ocenę zjawiska porośnięcia ich powierzchni grzybem płasniowym *A. niger* po 5, 10, 14, 21 dniach inkubacji. Na podstawie przeprowadzonych badań stwierdzono, iż płyta wiórowa jest bardziej odporna na atak grzyba *A. niger* niż sklejka. Najbardziej odporne okazały się próbki płyty wiórowej zaklejone żywicą UF z dodatkiem nano-SiO\textsubscript{2}. Wprowadzenie do żywicy klejowej nano-SiO\textsubscript{2} w ilości 2 cz.w./100 cz.w. żywicy znacznie ograniczyło i spowolniło rozwój zarodników na powierzchni płyty. W przypadku sklejek stwierdzono całkowitą brak ich odporności na pleśnienie niezależnie od rodzaju wypełniacza (skrobiowy lub nano-SiO\textsubscript{2}) zastosowanego w procesie zaklejania arkuszu fornirów.

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Standards in design and realisation of timber structures: PN-EN 338, PN-EN 14081-1 and PN-EN 15497

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Abstract: Standards in design and realisation of timber structures: PN-EN 338, PN-EN 14081-1 and PN-EN 15497. This paper is to present scope and differences between PN-EN 14081-1 and PN-EN 15497:2014 with special attention on design process and realization. Differences between old and actual version of PN-EN14081-1: and PN-EN 338 are also pointed.

Keywords: structural timber, structural finger jointed solid timber, strength class, standard, design

Design process requires legibility and clarity of the design and its results. Execution of the construction requires compatibility with the design project concerning used materials as well as solutions. The purpose of the building and construction standards is to show the rules and the properties of materials according to research and present knowledge. One of the main reasons of using standards is to get a safe and healthy construction. If the research shows that the standard needs to be changed or revised in some part, those changes are developed in standardization process and published in a form of annex or the standard is being republished with new dating.

More detailed analysis of basic regulations and standards concerning timber structures shows clearly that it is necessary to use present standards rather than the cancelled ones. The necessity of taking them into account, when the material is being changed in the process of realization.

EN 14081-1 – harmonized standard

This standard is the basis of marketing strength graded structural timber with rectangular cross-sections. Timber structures, as covered by harmonized standard, require following the regulations. According to regulation changing the regulations about construction products and assessment and verification of the constancy of performance systems - all construction products covered by harmonized standard subject to EU Regulation Nr 305/2011 and have to be CE marked. In reference to construction products covered by harmonized standard, the procedure of individual application is not applicable.

First of all, it is crucial to mention that Polish translation of standard EN 14081-1 from 2007 (replaced then by English version of PN-EN 14081-1+A1:2011) contained important mistake. Because of this mistake there are still on the market incorrect declarations of performance referring to initial type testing made by “estimation”. Because neither EN 14081+A1:2011 used currently in process of certification nor EN 14081-1:2016 (not yet published in OJ EU) are not translated into Polish, some people in Poland still use the old Polish version, cancelled many years ago. Meanwhile, apart from the mistake in translation, this standard was replaced by other one, dated 2011, which is currently the basis for CE marking. It is worth to mention here that the use of harmonized standards is to demonstrate that products – here structural timber and engineering timber products - comply with relevant EU legislation. The standard form 2011 will be used until the expiration of the transition period of the new standard, dated 2016-06, showed in publication in OJ EU.
14081-1:2016 replaces EN 14081-4:2009 and EN 14081-1:2005+A1:2011. The new standard introduces inter alia references to CPR in Clause 6 for Assessment and Verification of Constancy of Performance and Annex ZA. New requirements on Fire Resistance, release of dangerous substances, geometrical data and environmental issues are also pointed. Very important for Polish market (and unofficial Polish assignment of visual grade classes to strength classes acc to EN 338) is point 6.3.2.6. According to this point, tests indicated in EN 408 are obligatory for softwood species graded to:

- bending strength classes with a characteristic bending strength above 30 MPa
- tension strength class with a characteristic tensile strength above 21 MPa,

"Two pieces of timber from each grade produced during each shift shall be randomly selected and tested for tensile strength or edgewise bending strength."

It means in praxis, that if Polish, unofficial assignment of visual grade class KW for pine will be kept and introduced in the future to EN 1912 – all sawmills, where it is possible to get KW for pine, will be obligated to provide destructive tests acc to EN 408. Today, as indicated in the National Annex to EN 1995-1-1, pine in visual class KW is assigned to characteristic bending strength 35 MPa – so above 30 MPa, pointed in 6.3.2.6 of EN 14081-1:2016.

PN-EN 338

The standard contains strength classes of structural solid timber, both softwood and hardwood. It is referred in harmonized standard EN 14081-1 as a basis to classification – but the visually sorted timber needs to meet requirement of point 5.2.2 of EN 14081-1:2005+A1:2011:

“If the grade and species have been assigned to a strength class by EN 1912, the characteristic values for the properties shall be those given for the assigned strength class in EN 338; otherwise they are determined in accordance with EN 384."

Many papers, documents and projects in Poland still include references to EN 338:1999. Meanwhile the standard EN 338:2009 (PN-EN 338:2011) is suspended since Juni 2016 by EN 338:2016 an coexistence period just ends (EN 338:2009 = PN-EN 338:2011 is possible to use in procedure of conformity assessment up to 31.10.2016). Differences between old and new dating are profound. For structure designing safety, the most important is the change of characteristic value of compression perpendicular to the grain. Standard dated 1999 gave these values much higher than the current one. Using in design parameters coming from standard withdrawn more than 10 years ago, can lead even to the damage or failure of the building.

The current standard EN 338:2016 introduces new classes, marked with a letter T, as a novelty comparing to the previous versions. T-classes were used first time in EN 14080:2013 as determination of raw material, used in a production of glue laminated timber. The number by letter T indicates the value of the tension strength in MPa.
EN 338+EN 14081-1 vs EN 15497 and EN 14080

Design

Theoretically, Eurocode 5 is the only valid standard concerning timber structures, and conflicting national standards should have been withdrawn up to march 2010. According to national foreword, this standard replaces PN-B 03154:1983 and PN-B 03150:2000. Despite that, the old, withdrawn standard PN-B 03150:2000 is still often used in Poland to design timber structures – and also is still placed in Regulation concerning technical requirements for buildings and theirs location, next to Eurocode 5.

Because of dual references pointed in Polish Regulation mentioned above, it is obligatory to take into consideration normative references, coming from harmonized standards, at all stages of design process. It is also very important in every situation where replacing of materials used in construction is considered. EN 18081-1 doesn’t point EN 1995-1-1 as normatively referenced and as indispensable for its application. Only EN 1995-1-2 is pointed – it means that design acc to Eurocode is obligatory for all structures made of strength graded structural timber with rectangular cross section when structural fire design is needed.

EN 14080 and EN 15497 point EN 1995-1-1 as normative reference, indispensable for its application. So in Poland design of structures made of strength graded structural timber theoretically can base on the old, national standard PN-B 03150:2000 as long as this standard is pointed in Regulation concerning technical requirements for buildings and their location. (taking into consideration only aspect of normative references, pointed in EN 14081-1). Nevertheless in every case of planned/wished by investor change of materials from structural timber to structural finger jointed solid timber or glulam – it is necessary to redesign the structure basing on EC5. All action on structure must be taken according to Eurocode 1 in this case, as well as basis of design, structural safety and serviceability etc – according to Eurocode 0. De facto it is necessary to replace all calculations by new, if on the stage of execution change of material to structural finger jointed solid timber or glulam is done, when the project based preliminary on withdrawn Polish standard.

Realization

Changing of the material in process of realization (from solid wood to structural finger jointed solid timber or glued laminated timber) requires taking into consideration service classes. Not all types of elements are approved to work in all service classes. Standard EN 15497 defines types of glue, allowed in all three service classes and the ones allowed only in 1 and 2 class. When buying material made according to EN 15497 and not EN 14081, it is necessary to specify the service class in which the elements will be used. Solid wood in third service class requires additional protection, but structural finger jointed solid timber need also, to be produced according to the standard. The same applies to changing solid wood to glued laminated timber in service class 3. Glued laminated timber in 3. service class requires smaller laminations (to 35 mm in service class 3, while in 1. and 2. laminations up to 45 mm are used), apart from using proper glue. The issue of using proper material according to requirements may seem plain and out of place in this paper. However, the experience on Polish market shows that such obvious issues need to be discussed. It is more and more common to offer changing solid wood to structural finger jointed solid timber or glued laminated timber as much more better options. The other reason of such changes is the lack of availability of proper structural timber – with proper moisture (up to 18% in service class 1 and 2 and up o 23% in class 3), strength graded and certified. In many cases no one pays attention where the elements are going to be used. Use of the material that is not designed for
service class 3 may cause serious problems and using better and more expensive material will give no expected effects.

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The assumptions an algorithm for image analysis for the assay fronds growth of common duckweed (Lemna minor L.)

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Abstract: The assumptions an algorithm for image analysis for the assay fronds growth of common duckweed (Lemna minor L.). The assumptions of the algorithm aiming to automate and eliminate human error during the process of determining the duckweed (Lemna minor L.) growth used for the wood biomass ecotoxicity. The most effective filter channels of the image was selected.

Keywords: ecotoxicity, image analysis, duckweed, wood biomass

INTRODUCTION

Nowadays there is a tendency to use the eco-technology, which is environment-friendly technologies. Conventional obtaining ethyl alcohol from wood use polluting mineral acids. In the "green" technology, mineral acids are replaced by hydrolytic enzymes - compounds completely biodegradable. The disadvantage of this technology is the high price of natural enzymes used to facilitate the alcoholic fermentation.

Due to the high price of enzymes is necessary to verify that among the numerous wood extractives, is not an inhibitor of enzymes which slow down or completely stop the enzymatic hydrolysis and bioethanol technology. Examining all potential inhibitors of the enzymatic hydrolysis, it is practically impossible because of the time- and cost effectiveness testing. If there is a correlation between the ecotoxicity and inhibiting its activity, could be used to examine easier parameter, toxicity is predictive of the ability of inhibitory substances.

Ecotoxicology assesses the impact of toxic substances on living organisms and helps to protect ecological systems against harmful effects of synthetic chemicals (Rejmer 1997). One of the most vulnerable ecosystems is the aquatic ecosystem. This is because of the ease which the harmful substances can penetrate into the aquatic environment, and the speed which them spread in the water. In the aquatic environment, some toxins may be subject to accumulate in organisms, plants and animals living there (Wiaderna 2011).

Aquatic toxicity tests are carried out for the different groups of organisms: fish, aquatic invertebrates, macrophytes, phytoplankton, organisms living in the bottom sediments. Selection of the most appropriate organism is based on a role which it plays in the ecosystem and its sensitivity to the substance test.

Vascular plants are rarely used in toxicity tests. Such research typically used common duckweed (Lemna minor L.) or gibbous duckweed (Lemna gibba L.) (OCSSP 2012). Its small size, ease of laboratory culture and fast reproduction prejudice the applicability of it as research material.

Determination of wood biomass aquatic leachates toxicity toward common duckweed (Lemna minor L.) is to investigate of growth inhibition specified by number of fronds - qualitative analysis, dry biomass and chlorophyll content - quantitative analysis. Qualitative analysis is very time consuming and there is high risk to make many mistakes during counting. It is difficult to define the young frond parameters which includes to the
duckweed growth. Accordingly, picture taken under the same lighting conditions can accelerate the counting of the fronds, however, does not eliminate human reliability.

An attempt was made using image analysis techniques to create an algorithm that will determine the fronds growth and chlorophyll content based on the counting area. The paper presents assumptions an algorithm that returns the area occupied by the fronds, taking into account the area affected by chlorosis or necrosis.

MathCAD is commonly use computer algebra system (CAS) software, used to solving engineering problems, mathematical modelling, and creating user friendly calculate sheets, due to its user-friendly interface and natural recording of mathematical formulas. It is used in variety of scientific research, starting from social and behaviour sciences to engineering, for example: mechanical design, pipeline design, chemistry, thermodynamic, bio-system engineering or used in general purpose scientific data analysis (Carrasco et al. 2014, Shayane et all. 2015).

Mathcad has the ability to load images saved in one of the popular extensions (eg. jpg, gif, bmp, tiff and others), and present it as a matrix array equal to resolution of image, with the presentation of the channel for one of the colour space (eg. RGB, HLS, HSV). This allows to load images of investigated duckweed, and make appropriate algebraic calculations to remove the background and automatically calculate area of duckweed, taking into account the area affected by chlorosis or necrosis. This forces to find adequate colour channels and cut-off values for unnecessary data.

MATERIALS AND METHODS

Software used to develop algorithm was MathCad Prime 3.0 software run on PC computer, mobile workstation, equipped with quad-core Intel i7 processor and 16GB RAM. Photography was taken with Nikon D750 DSLR, with macro lens AF-S NIKKOR 60/2.8G, and Nikon Speedlight SB-910, attached to the Manfrotto 190CXPRO4B tripod, equipped with ball head.

RESULTS AND DISCUSSION

To develop the algorithm, various conditions was tested. It is necessary to check its performance in controlled conditions. To test algorithm performance, graphic representing various conditions was created: perfect green, green with interference, green color and yellow (represent necrosis), and final verification based on real picture. Graphics from Table 1. was used.

| 1. | ![Image](image.png) 10x10 pixel graphic, with four 5x5 pixel rectangle. Two colour black, with RGB (7,7,7), one green – RGB (0,148,0), and one red – RGB (255,0,30). Green represents 25% area. |

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Table 1. Graphics used in filtrating algorithm development
The algorithm idea is to create a method to automatically count surface of duckweed frond taking into account and remove background and damaged fronds.

Based on MathCAD image processing functions, the following colour space component was taken into considerations:

- **RGB-R**: Red component from RGB colour space,
- **RGB-G**: Green component from RGB colour space,
- **RGB-B**: Blue component from RGB colour space,
- **HLS-H**: Hue component from Ostwald HLS/Smith’s HSV colour model,
- **HLS-L**: Lightness component from Ostwald HLS colour model,
- **HLS-S**: Saturation component from Ostwald HLS colour model,
- **HSV-S**: Saturation component from Smith’s HSV colour model,
- **HSV-V**: Value component from Smith’s HSV colour model,
**Idea scheme of algorithm**

The first step in algorithm is to read chosen colour space component among components taking into considerations, and represent it as matrix. Next step is to automatically calculate the number of pixels in the image. Then filter the pixels corresponding to duckweed and cut off background pixels by changing it value to 0. The cut-off value was determined based on a histogram. Last step is percentage calculation amount of filtered pixels in comparison with all pixels in image, and quality verification of algorithm based on map graphs, that highlights cut-off values.

**Step 1 – Verification of usability of colour model components**

In a first step of developing the algorithm, verification of usability of considered colour model components was made.

**Table 2. Results of usability of colour model components**

<table>
<thead>
<tr>
<th></th>
<th>RGB-R</th>
<th>RGB-G</th>
<th>RGB-B</th>
<th>HLS-H</th>
<th>HLS-L</th>
<th>HLS-S</th>
<th>HSV-S</th>
<th>HSV-V</th>
</tr>
</thead>
<tbody>
<tr>
<td>Graphic 1.</td>
<td>+/-</td>
<td>+</td>
<td>+/-</td>
<td>+</td>
<td>-</td>
<td>+/-</td>
<td>+/-</td>
<td>-</td>
</tr>
<tr>
<td>Graphic 2.</td>
<td>-</td>
<td>+/-</td>
<td>-</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
<tr>
<td>Graphic 3.</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>+/-</td>
<td>-</td>
<td>-</td>
<td>-</td>
<td>-</td>
</tr>
</tbody>
</table>

Based on tests results presented in (Tab. 2.) colour model components were divided into three groups by green filtration suitability. The first group of colour model components that detect the green colour in ideal conditions included RGB-G and HLS-H. The colour model components were identified as the main parameters of green pixels filtration algorithm. In the case of the toxic extractives concentration for duckweed, will be noticeable signs of chlorosis (local white discoloration) or necrosis (fronds decay - yellow / brown colour). Yellow and brown colours have similar components of RGB-G at the green colour found in duckweed fronds so it is necessary to complement filtrating algorithm for an additional parameter. The second group of colour model components can not detect the green colour in ideal conditions, but may be used as an additional excluding filters, for example water with colour cast from the wood extracts. Additional filter used RGB-R (can be used to the exclusion of red colour), RGB-B (can be used as an exclusion necrosis due to a significant difference between healthy fronds - green and with necrosis - yellow/brown). Components HLS-S or HSV-S, which are responsible for determining the saturation. They can be used as an additional filter which rejects pixels with different saturation. The third group of colour component represents only the colour brightness in two colour spaces (HSV-V and HLS-L). It was rejected due to insufficient precision filtering.

**Step 2 – Verification of chosen colour components on real conditions**

In the first step it was important to verify most effective component to detect green colour among all colour models. Based on the results obtained in step 1, it was found that a single colour model component can not sufficiently precise filter out background of frond. For
this reason the main component was selected, and secondary component as an additional filter was added. To verify the algorithm correctness RGB-G was selected as a main colour component and RGB-B as a complementary.

CONCLUSIONS

It is possible to create an algorithm that counts the number of pixels, there is a need for make a calibration allows the conversion of pixels on the area occupied by the duckweed fronds in SI units. The algorithm takes into account fronds size, which was neglected in the conventional qualitative analysis. They will be conducted further research on the selection of the most accurate of colour components combination for counting pixels corresponding to the duckweed fronds in real conditions. It is possible to use an algorithm to estimate the size of chlorosis and necrosis after making minor changes.

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Decoration of furniture inspired by human anatomy

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Abstract: Decoration of furniture inspired by human anatomy. Under the auspices of Groningen Museum works designer Studio Jacob, whose projects is also furniture. The collection presented in museum shows the latest pieces of work of Dutch designers surprising viewers not only by some designs but also their inspirations. The presented below cabinet stands out not only by vanguard construction but also the way of decoration of its walls and door frames inspired by human anatomy.

Keywords: furniture, cabinet, painting studio Job, Groningen Muzeum

INTRODUCTION

The designer’s Studio Jacob which was founded in Groningen (The Netherlands) has created a whole range of classic forms of furniture known for years. It was distinguished by specific albeit controversial painting of individual elements. The products and their prototypes were shown in Groningen National Museum which sponsored the Studio. It seems reasonable to discuss the designing possibilities of contemporary designers on the example of the piece of furniture covered with mural inspired by human anatomy. [KLOOSTRA 2011, NRC Weekend 2011, Van den ZIJPP 2011].

THE HISTORY OF THE BUSINESS AND STUDIO JOB

In the past ten years, the Groningen Museum has accumulated a substantial collection of work by Studio Job, which consists of Job Smeets (1970) and Nynke Tynagel (1977) Obydwoje both graduated from the Design Academy in Eindhoven. Studio Job’s virtuoso handling of extraordinary materials and extreme techniques. But the archetypical and monumental objects show, above all, an expressive engagement at the interface of art and design. In 1998, Smeets founded Studio Job and two years later, after her graduation, Tynagel joined him in the enterprise. The duo became known for their caricatural and non-scaled designs, by means of which they gave commentary on widely held ideas within the world of design [www.lindavanwaesberge.be].

Smeets and Tynagel have presented their work in leading galleries all over the world and many private and public collections now contain examples of this work. The Groninger Museum has been following In December 2010, as a
component of the building revitalization that has just been completed, the Museum opened a new reception area conceived by the designers: the Job Lounge. Shortly he gained international fame for special projects on the border of art and design. This mutual interpenetration is an important asset of the works presented in Groningen National Museum and brings in new content in the activities of designers [Van der ZIJPP 2011]. They concentrate on products, which are not met in ordinary trade. They are not exposed for sale, but individual objects and installations are defined by the term "pattern". It is work of Studio Job that is doing creative ferment and bringing new content for the discussion on the development of design.

The solo exhibition is the result of a unique relationship between the designers and the Museum, where the Museum occasionally assumed the role of sparring partner as well as that of co-producer. The exhibition shows the exceptional interaction and most important artistic developments of Studio Job. The key works, determinative series, and the products of major co-operative ventures with external partners illustrate the versatility and conceptual stratification of the work of Studio Job. Thanks to the presentation of a large and important section of the oeuvre, the mutual connections within the body of work and their artistic significance are brought to the forefront.

**Figure 2.** Quack cabinet, 2011 (open)
marquetry of Indian rosewood, polychrome dyed veneers, multiply wood, polished and patinated bronze castings, brass, glass panels, cork, labels, PU coating, unique piece / commission, 187 x 200 x 60 cm. Collection Van sint fiet
Although functionality and availability of the mass production were important ideas in the XXth century, Smeets and Tynagel at the beginning of this century willingly go back to the experience arising from the time before the Industrial Revolution [RÓŻYCKA 2005]. Their formal language of design is characterised by the use of traditional materials like: marquetry of Indian rosewood, polychrome, veneers, multiply wood, bronze, castings, brass, glass panels, cork, labels which relate to decorative art of old times which results in creation of unforgettable forms and emanates specific climate. One can notice fascination of European decorative tradition which is important in appreciation of unique crafts and its application in furniture [RÓŻYCKA 2005]. The creators fully realize that they design mostly unique pieces and objects in limited editions and not for the mass market allowing confront the viewer with beauty every day. Achievements in the field of furniture design are shown on the example of "Quak cabinet (Fig.2 - 5). The storage unit presents design duo Studio Job's Smeets and Tynagel's signature interest in the traditional veneer application technique of marquetry.

Figure 3. Quack cabinet, 2011 (closed), marquetry of Indian rosewood, polychrome dyed veneers, multiply wood, polished and patinated bronze castings, brass, glass panels, cork, labels, PU coating, unique piece / commission, 187 x 200 x 60 cm, collection van sint fiet
Figure 4. Quack cabinet, (detail)

Figure 5. Quack cabinet, 2011 (187 x 200 x 60 cm) and rose table, 2005 (225 x 76 x 100 cm), marquetry of indian rosewood, polychrome dyed veneers, multiply wood, polished and patinated bronze castings, brass, glass panels, cork, labels, PU coating
Collection Cibone, Tokyo
The construction of furniture is traditional, but decorations of door, side walls, legs and also back wall is made in traditional technique and using veneer rosewood. Imaging performed in this technique is further enhanced by painting elements using templates. On the back wall of the wardrobe one can see painting inspired by human interior - anatomy and bones of human torso, bones of the chest with well visible white ribs. The background consists of twisted arteries and vines creating ornamental design. In the centre of the picture one can distinguish two brown kidneys and below an attentive viewer can perceive fragments of twisted intestine. Among arteries and vines painted in different colours one can notice bones and surgical instruments (for example clips to blood vessels) and glands. The picture is surrounded by bones of the arms and legs. The authors part of arteries coloured in blue and part of vines in red, which summing up gives a bit complicated macabre design.

This rich decoration is differs from modernistic rules of furniture performance. The usage of decoration is not limited only to walls of furniture but the decoration in the form of arteries and vines are extended to elements of door frame. This kind of decoration leads to aesthetics close to abstractionism. The shelves were made from thick-walled glass so as not to cover the painting. On the whole it intuques and stimulates reflection.

The materials used in the projects of presented furniture is also rosewood, plywood, glass, polychrome paintings, polished and patinated bronze.

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Changes of functional properties of materials used in wood industry after ion implantation process

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Abstract: Changes of functional properties of materials used in wood industry after ion implantation process. The paper presents an information about real and potential application of ion implantation method in wood industry as regards the adhesive properties, the antimicrobial properties and the decoration of wood and wood-based materials.

Keywords: ion implantation, adhesion, antimicrobial properties, decorative properties, wood industry

INTRODUCTION

Ion implantation method [1-2], used generally in metal and semiconductor industry, is often applied in non-conventional applications, e.g. in mineralogy, biology or textile industry. These research investigations are conducted mainly in Asian countries, like Thailand, China or Turkey.

The scientists from Thailand use ion implantation for many years for changing the optical properties of minerals. These are: thermoluminescence of topazes implanted with transition metals (like Cr, Fe, Co, W) [3-4], change of colour, purer colour, clarity, transmittance and lustre of oxygen, nitrogen or argon implanted rubies, sapphires or corundum [5-12].

The improvement of the above mentioned properties is used both in optics, optoelectronics, photonics and tooling, as well as in gem industry of Thailand, very important for national revenue because, for example, the price of ruby is mainly determined by its colour.

Ion implantation technique is faster and cheaper than the heat treatment, commercially used for the improvement of quality of gemstones.

Ion implantation to the biological objects is a new discipline, initiated in China about 30 years ago. Due to its high mutation rate and wide mutational spectrum with relatively low damage in the organisms (like plants, e.g. seeds, microbes, yeast and even animals), the low energy ion implantation is widely used in agriculture and horticulture.

There are many examples of the application of nitrogen, argon or carbon ion implantation in breeding of: rice, soybean, maize, wheat, buckwheat, tomato, sweet potato, tea, peanut, tobacco, jatropha, cotton, rose, carnations, chrysanthemum, petunia, etc. The low energy ion beam treatment of a plants can induce e.g. rapid growth in various plant species (shorter growing period), higher germination, higher yield, higher seed quality, longer storability, higher resistance to viruses, microbes or diseases, higher drought resistance, decorative qualities of flowers [13-26].
The selected, ion beam mutated bacteria can be useful in food industry (improvement of the fermentation ability, biocontrol of pathogens) or in the agriculture (suppression of conidia germination of the selected fungus, reducing of symptoms caused by the diseases) [26-27]. Similarly, ion treated yeast are used to the fermentation [28].

The example of ion beam effect on animal can be nitrogen implantation of the silkworm’s ovum. Modified silkworm chrysalis had an increasing trend of entire cocoon content, layer number and incrassate fibril [13].

Apart from the practical applications of ion implantation in biology, the new areas of study in the field of life sciences emerge. There are e.g. the health risk of low-dose radiation in the environment [26] or therapy of human cancer [29-30].

Ion beam treated cotton, polyester, polyethylene or polyamide textiles can be next example of non-conventional application of ion implantation method. This pre-treatment change e.g. the abrasion/wear resistance, pilling resistance, electrostatic properties, flame retardancy, hydrophilicity/hydrophobity, waterproof, bactericidal or electrical resistivity. For example, Cu, Pd, Ag or Pt ion implantation improve the electrical properties and can be used in textile-based electronics. C, N, Al, Ti and Cr implanted ions enhance the mechanical properties and pilling of the modified textiles. C and W improve the flame retardancy and silver used among others in bandages improve the antibacterial properties [31-36].

Increasingly, ion implantation is perceived as bioactive tailoring method [38]. The modified region is not an additional layer, hence no adhesion problem occurs (no delamination), and a change of dimensions and of the surface finish of the implanted material is negligible.

By this paper, we would like to extend the use of classical ion implantation technique in few non-conventional applications in biology and wood processing.

IMPROVEMENT OF THE ADHESION OF THE MATERIALS USED IN WOOD INDUSTRY

In the literature, there is practically no information about ion implantation of wood and wood-based materials. Only, in Ref. [39], nitrogen implanted cellulose-polyvinyl alcohol-silica composite for biomedical applications was presented.

The ion modification of big plates of large furniture boards is a problem due to relatively small vacuum chambers of typical implanters. The implantation of the laminates or edge banding tapes for furniture is much easier. The authors of this paper investigate the changes of wettability of gas ion damaged edge tapes. The first results are promising.

IMPROVEMENT OF THE ANTIMICROBIAL PROPERTIES OF WOOD AND WOOD-BASED MATERIALS

For many years, silver is known for its antimicrobial (including antibacterial and antifungal) properties. This feature is used in the variety of medical and cosmetic products, like creams, ointments, soaps, bandages, surgical tools and catheters to prevent or fight infection [40-41]. Zinc is the second element with similar properties. These elements, separately or combined together are used to improve antibacterial properties of different materials, like stainless steel, titanium or ultra-high molecular weight polyethylene (UHMWPE) [42-47].

The synergistic effects of co-implantation of Zn and Ag was presented in Ref. [46]. The reduction of the content of E. coli bacteria was at level 39% for samples implanted with Zn, 79% for Ag and 99% for Zn+Ag, in comparison to the non-treated samples. The reduction was 45%, 96% and 99% for Zn, Ag and Zn+Ag, respectively, for S. aureus bacteria.
We propose the using silver and/or zinc ion implantation e.g. to wooden kitchen accessories.

ION IMPLANTATION AS A METHOD OF THE DECORATION OF WOOD AND WOOD-BASED MATERIALS

Ion implantation using the stencils allows the patterns on the surface of wood and wood-based materials. In this case, the range of implanted elements may be wider. This process can be used e.g. for the decoration of wooden casket for jewellery.

Fig. 1 presents the effects of Ti ion implantation of beech wood, using stainless steel stencils. The stencils were manufactured in Institute of Electrical Drives and Machines KOMEL in Sosnowiec in Poland. Ion implantation was performed in National Centre for Nuclear Research Świerk in Otwock in Poland.

Fig. 1. Stainless steel stencils and the results of ion implantation of beech wood

Modification process was performed with 30 kV acceleration voltage. The ion beam current was at level of 1 mA. The ion fluence was a few 1e15 per cm². The exposure time was about 2 minutes.

The created pictures are permanent. We can see the high precision of the projection of the stencils.

CONCLUSION

Based on a review of literature, we can conclude that ion implantation is not popular in the wood industry. It seems, that the presented examples of applications show the potential of this method, especially in the niche applications.

Acknowledgment

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Streszczenie: Zmiana funkcjonalnych właściwości implantowanych jonowo materialów stosowanych w przemyśle drzewnym. W artykule przedstawiono informacje o rzeczywistych i potencjalnych zastosowaniach metody implantacji jonów w przemyśle drzewnym w zakresie potencjalnych zastosowań metody implantacji jonów w przemyśle drzewnym.
zmiany właściwości adhezyjnych, antybakteryjnych i dekoracyjnych stosowanych materiałów.

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Compreg - machinability during drilling

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Abstract: Compreg – machinability during drilling. The article presents the results of tests of machinability of compreg. Machinability was evaluated during drilling. The value of the axial force and cutting torque for 7 variants of feed per revolution and the quality of the drilling process were examined. Cutting forces were measured using piezoelectric Kistler sensor and Labview software. The quality was determined on the basis of digital photos taken using macro lens, two quality indices were calculated. It turned out that the assessment of machinability during drilling requires an analysis of axial force and cutting torque. One of the analyzed quality indicators observed outside the nominal diameter of the hole, was strongly dependent on feed per revolution. The impact of feed on the second indicator was much less clear.

Keywords: cutting forces, quality, drilling, compreg, lignofol

INTRODUCTION

Compreg is a special wood composite material with a very exceptional mechanical and functional properties, extremely hard and durable. It is used where resistance is required for tough operating conditions: gears, rollers and slides, industrial trays or tables of woodworking machines. However Compreg is not just a material for industrial use. Compreg manufacturer claims that despite this material hardness, it is relatively easy to machine. Subject of this paper is experimental test of Compreg machinability specified for the process of drilling for the criterion of cutting forces and quality of cutting. Both of the criteria are important, practical indicators of machinability [Górski, Podziewski, Szymanowski 2010; Podziewski, Górs,ki 2011,2012]. The results of experimental study of these aspects are presented in this paper.

MATERIALS AND METHODS

Tests were conducted using standard CNC machine tool BUSELLATO Jet 130. Drilling was carried out using a brand new single-bladed PCD drill with seven variants of feed per revolution: 0,1 mm; 0,15mm 0,2 mm; 0,25mm 0,3 mm; 0,5 mm; 0,7 mm, and constant spindle speed - 6000 rpm. During processing tested material was fixed on a platform with piezoelectric sensor. The platform was connected to PC computer with LabView environment installed in which the measurement and recording of feed force (F) and torque (M) signals were made. Cutting quality was analyzed for every drilled hole separately at the entrance and the exit of the drill. All drilled holes were photographed and measured using PC computer (fig.1). Obtained data were used to calculate two cutting quality indicators. Two following types of quality indicators (based on Fd max [Davim, Clemente, Silva 2008]) were determined:

\[ A = \frac{D_{\text{max}} - D}{2} \]
\[ B = \frac{D - D_{\text{min}}}{2} \]
where:
A, B – two different (external and internal type) drilling quality indicators,
\(D_{\text{max}}\) – a diameter of a circle covering total damaged area which were observed outside the hole,
\(D_{\text{min}}\) – a diameter of a circle covering a real hole (this diameter was generally less than the nominal diameter because of damages which were observed inside the hole),
\(D\) - nominal diameter of the hole.

Fig. 1 Quality analysis: a) Digital camera with macro lens, b) Scheme of cutting quality measurements, tested material: entrance of the drill bit “I”, exit of the drill bit “O”

RESULTS AND DISCUSSION

Results of measured feed force and drilling torque was presented on fig 2 and fig 3. Relationship of both forces and feed per revolution is almost linear. Figures represent also corresponding values obtained for MDF [Podziewski et.al. 2014]. MDF is commonly considered “easy to machine”. Results for Compreg were from 2 times to 4 times higher for cutting torque and from 4 times to 7 times higher for axial force.

Fig. 2 Relationship between feed per revolution and cutting torque

Fig. 3 Relationship between feed per revolution and axial force
The analysis of quality showed that the feed per revolution ($\Delta$) had a significant and approximately linear effect on the quality indicator $A$ (Fig. 4). The value of the coefficient of determination ($R^2$) calculated for this relationship was 0,99 (for the entrance of the drill) and 0,93 (for the exit). The effect of feed rate on the quality indicator $B$ (Fig. 5) was much less clear. Quality was worsening a little from the entrance side of the holes, but no significant linear dependence was found. The exit side of the holes has a visible improvement in quality for greater values of the feed per revolution. For the lowest feed quality indicator $B$ had the highest value, and the values were becoming lower fast to the 0,3mm feed then velocity of the changes dropped significantly.

![Fig. 4 Relationship between feed per revolution and quality indicator A value](file)

![Fig. 5 Relationship between feed per revolution and quality indicator B value.](file)

**CONCLUSIONS**

The results of presented above tests allow to formulate following conclusions.

1. Machinability during drilling of Compreg based on cutting forces is from 2 times to 7 times greater than MDF. Full designation of that property of Compreg requires measurement of both axial force and cutting torque.
2. Quality indicator $A$, observed outside nominal diameter of the holes turned out to be highly dependent in linear wayon feed per revolution.
3. The effect of feed rate on the quality indicator $B$ was much less clear and uneven.

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Influence of feed per tooth on particle size of chips created in particleboard peripheral milling

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Abstract: Influence of feed per tooth on particle size of chips created in particleboard peripheral milling. Presented paper regards comparison analysis of chip size distribution of shavings obtained during peripheral milling of particleboards. On its basis the influence of feed per tooth on mass proportion between chip fractions for up- and down-milling was determined. It was proved that increasing of feed per tooth with constant depth of cut, the chip size distribution changes by increasing particles from the dimensional range 125-250 µm and in the same time, decreasing bigger particles from the range of 500-1000 µm.

Keywords: particleboard machining, milling, particle-size distribution

INTRODUCTION

Processing of wood and composites based on it concerns many different types of operations. During these operations small waste particles (saw dust, chips, shavings, etc.) are created. The mass and particle size distribution of chips depend on type of processed material, type of machining, and its parameters.

Wood composites machining compared to a natural wood, is a source of much higher fraction of small particles due to the fact that they are made of previously fragmented wood. There is an influence of fragmentation degree of wood used to production of wood composites. Processing of composites made of wood fibers (fiberboards) creates significantly more smallest particles (Chung et al. 2000) which can disperse in the air surrounding work stations than processing of other types of wood campsites such as composites made of chips (particleboards) and especially layered materials (plywood) made of wood veneers (Rogozinski et al. 2015).

Because particleboards are often used in furniture industry as a basic construction and decorative material, the problem of chips and especially dust created during processing is very significant (Dolny and Rogoziński 2010, Dolny et al. 2005). Many furniture companies should reduce the air pollution caused by dust. Dust emission in particleboard processing is strongly connected with formaldehyde emission, which additionally decreases working conditions. So the reduction of these emissions in furniture production is necessary. High dust creation can be reduced by proper selection of processing parameters. It have to be based on the knowledge how the processing parameters influence on the chips creation.

There are many adjustable processing parameter of milling - feed speed, rotational speed of a tool, number of teeth, tool geometry, cutting depth, etc., which can influence on the particle-size distribution of chips created. Milling process can be also characterized in comparative way by other parameters such as cutting speed, feed per tooth, average chip thickness calculated or determined basing on the processing parameters. So the influence of every parameter on the particle size of chips should be determined in order to estimate a
possibility of reduction of the dust emission on work stations in furniture industry (Kos et al. 2004, Rogoziński and Ockajova 2013).

In this paper the feed per tooth was selected as a parameter, which influence on the particles-size distribution of chips created during milling of particleboard was determined.

MATERIALS AND METHODS

A laminated particleboard peripheral milling was performed in order to verify how the feed per tooth influences sizes of shavings obtained by machining. As a material for experiments served commercially available melamine coated (non-structured) 18 mm thickness particleboards produced by Kronospan company. Edges of the board sheets were trimmed in order to remove loose structure material. Average density of the remaining panels were 651±3 kg/m³. All the machining processes directed toward obtaining the shavings, were performed on a down-spindle Felder F900 moulder (motor power 5.5 kW). The state of the machine might be defined as excellent. Feeding of the material was ensured by powered rubber roller feeder with adjustable feed rates. A tool used during tests was 125 mm in diameter and 40 mm of height milling head with four changeable straight edge double-sided inserts (Fig. 1.). The cutting edges were changed into brand new sharp ones for each experimental case in order its microgeometry not to influence the resulting chips.

![Figure 1. Cutting head used in experiment](image)

The cutting parameters were chosen to ensure three values of feed per tooth ($\Delta z$): 1.6, 2.6 and 4.5 mm. The depth of cut was constantly equal 1 mm. Two different groups of cases concerned up- and down-milling processes were examined. For each single experimental case over 5 kg of machining chips were collected separately with use of single-stand dust extraction system. After manual mixing of particles a random sample of about 200 g was taken and subjected to screening on Retsch AS 200 laboratory sieving vibrator. Sizes of the sieves meshes used in the test were: 1, 0.5, 0.25, 0.125 and 0.063 mm. Particles passing thru the smallest mesh were also collected and qualified as having size < 0.063 mm. Each vibrating cycle took 600 s. Chips remaining on each sieve (fraction) were then weighted with the balance of accuracy 0.01 g. The test sieving was three times repeated, and the average value of them was taken as a final result of particle-size determination.

RESULTS

After the experiments and measurements have been performed as described in previous section, the results obtained have been split into two groups concerning separately up-milling and down-milling processes. Figure 2 displays cumulative distribution of chips
mass shares for up-milling. Cumulative curves visible have a common shape and they shows that shavings from undertaken machining test rarely reach the size of 1 mm. Quite steep increase in the range of small chip sizes (upto 500 µm) means, as it was pointed before, that machining of particleboards generally leads to production of numerous small shavings comparing to natural wood (Dzurenda and Orłowski 2011).

Figure 2. Cumulative distribution of chips mass shares for up-milling

Figure 3. Cumulative distribution of chips mass shares for down-milling
Figure 4. Influence of feed per tooth on mass shares of different chips fractions

It is clearly visible that the low feed per tooth (1.6 mm) curve is shifted among others to the left, indicating that with lower feed per tooth a bigger amount of small particles is
generated. Contrary, with increasing $\Delta_z$, higher masses concentrate in bigger size fractions. This is most likely the effect of the increased theoretical single chip volume, for high feed per tooth. A higher theoretical chip volume augment the probability of consisting bigger pieces of particleboard structure.

In case of down-milling (fig. 3) the graphs are very similar to these of up-milling, so again we may conclude that particleboard machining leads to high fragmentation of wastes. The more detailed differentiation of up- and down-milling was described previously (Pałubicki at al. 2015). In order to make more detailed analysis of influence of feed per tooth on chip’s dimension distribution separated graphs of feed per tooth vs. mass shares for each range of shavings size are shown on the figure 4. The lower the position of the curves in the graph, the lower the mass share of specific fraction. An inclination of curves specifies the change of mass share with the feed per tooth change. It is clear that the highest mass concentration exists in 250-500 µm range, however it is quite stable (c.a. 5% of mass share change) with the change of $\Delta_z$. Next two ranges with the highest mass shares are 125-250 µm and 500-1000 µm. In these cases their values are oscillating between 10 and 30% of shavings mass, depending on feed per tooth. For 125-250 µm range the mass share clearly shows a negative correlation with feed per tooth.

On the other hand the 500-1000 µm range is the most positively correlated to $\Delta_z$ among other fractions. It might be stated that the increase of feed per tooth in the examined range (1.6 – 4.5 mm) leads to shifting some 15% of waste mass from 125-250 µm range to that of sizes 500-1000 µm, with all other fractions staying on more or less constant level. 

Up- and down-milling both exhibit analogical trends, however in down-milling the mass shares seem to be related to the feed per tooth more linearly while in up-milling these relations are more sophisticated. This might be connected to the phenomenon described by Wong and Schajer (2003) who found three different stages of chip creation in up-milling of particleboards: rub, scrape and “cohesive chip”. In down-milling the cutting starts with non-zero chip thickness and therefore only “cohesive chip” is produced.

CONCLUSIONS
The particle size distribution of shavings created in peripheral milling of laminated particleboard showed high mass share of fine particles up 500 µm. Feed per tooth influences the granularity of chips from machining. Especially shares of particles from size ranges 125-250 µm and 500-1000 µm depended on feed per tooth parameter. Its increase causes diminution of smaller particle fractions and augmentation of bigger (500-1000 µm).

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Streszczenie: Wpływ posuwu na ostrze na wielkość wiórów powstałych przy frezowaniu płyty wiórowej. W pracy przedstawiono porównawczą analizę wyników badania składu ziarnowego wiórów powstałych w czasie frezowania płyt wiórowych. Określono na jej podstawie wpływ wartości posuwu na ostrze na wzajemne proporcje frakcji wymiarowych powstałych przy obróbce współbieżnej i przeciwbieżnej. Stwierdzono, że wraz ze zwiększaniem wartości posuwu na ostrze następuje zmiana w składzie ziarnowym powstałych wiórów, polegająca na znaczącym zmniejszeniu się zawartości cząstek o niewielkich wymiarach w przedziale 125-250 µm i zwiększeniu zawartości cząstek większych, z przedziału 500-1000 µm.

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Branding of Polish furniture brands and their competitive position

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Abstract: Branding of Polish furniture brands and their competitive position. The article concerns the subject of branding activities of Polish furniture brands. There has been clarified the concept of branding and description of tools used by brands so that consumers remember them permanently. There has been presented the results of tests, which were carried out with the use of an online questionnaire survey, on a group of 150 people. 10 Polish furniture manufacturers, from different segments, were taken into consideration. Respondents provided information on their knowledge about given entities and the effectiveness of specific branding tools. Furniture buyers most frequently use catalogues and corporate websites in search of information. As the results of the survey show, numerous official stores and intense advertising, both in the urban space and the media, have the greatest impact on brand recognition.

Keywords: branding, furniture brands, competitive position

INTRODUCTION

The furniture branch is one of the fastest growing sectors of Polish industry. Poland is in the third place in Europe, and in the fourth place worldwide in terms of furniture export [Polska trzecia w Europie pod względem eksportu mebli…]. According to Jan Szymaka, President of the Polish Chamber of Commerce of Furniture Manufacturers (OIGPM), recent rates show that, from the beginning of 2014, Poland has noted an incremental 8% increase in production and sales both in Poland and abroad. The increase in the sales of furniture on the Polish market is affected by consumer attitudes. Polish people change furniture more often, looking for new trends and a good design. Prosperity in the housing market is also beneficial for the furniture industry. According to data supplied by GUS (the national statistical office), in the first eight months of 2016, 98.2 thousand houses were completed, which is an increase of almost 11% in comparison to the same period a year earlier. All of the above aspects greatly affect the development of production and sales on the domestic market [Polscy meblarze na fali…].

The Polish furniture market currently comprises about 25 thousand entities [Polscy meblarze na fali…]. Each year, their activity is assessed in numerous rankings. One of them is the Ranking of Furniture Manufacturers, organized by the monthly magazine "Meble Plus". The aspects that this ranking evaluates are as follows: the turnover reached by a given store in relation to a manufacturer, sales contacts, participation of a given manufacturer in creating and updating the display in a given store, the quality of promotion material provided by a manufacturer, the quality of warranty and non-warranty service and the quality of complaint handling. Points are granted by furniture stores on the basis of a survey. The top three producers of cabinet furniture in 2016 are: Fabryki Mebli Forte, Meble Wójcik and Black Red White, followed by Mebin, Bydgoskie Meble oraz Szynaka Meble [Michalik B., 2014]. The results of the above furniture brands in the ranking are largely affected by their high competitive position. Competitive position is the position of a company, its products or services on a broadly defined market [Kleczek R. et al., 1992]. Undoubtedly, to become known on the market, it is necessary to build a brand that will be recognisable by consumers. Brand awareness alone is not enough, as in order to achieve market success, companies need to be able to stand out and translate this into a large sale with high margins.
Branding. Jak zbudować markę i na niej zarabiać. In order to achieve this, a marketing tool called branding is used.

There are many definitions of the concept of branding, both superficial and more complex ones. "The Entrepreneur" business encyclopedia defines it as "the marketing practice of creating a name, symbol or design that identifies and differentiates a product from other products" [www.entrepreneur.com]. Niemayer M. (2016) claims that a brand is neither a logo, a corporate identity system, nor the product itself, but it is a feeling and a strong emotional response of a consumer. Godin S (2009) defines it similarly: "A brand is the set of expectations, memories, stories and relationships that, taken together, account for a consumer’s decision to choose one product or service over another." At this point, the "brand triad" is worthy of mention, as each brand is characterised by different behaviour, communication and design. The order of the triad's elements sets priorities in thinking about the brand. Behaviour is the most important. It determines the sphere of communication, that is, promises. The visual plane is a form of expression of the other two elements. Consistent and reliable brand is the one which accomplishes its declarations and looks adequately to what it presents. [Mierkowski W., Rozen A., 2015]. Sinek S., (2011) says that branding begins with the question: why? It is fundamental to understand why and for what reason brands carry out their activities (know-why). Next, it is important to answer the question: with whom and for whom the brand wants to operate (know-who). Employees who understand and identify themselves with activities of the brand will be able to convince consumers to it. Another important aspect is the awareness of what the brand is supposed to deal with (know-what), and only then the specific knowledge of the field (know-how). In other words, if we know why, with whom, for whom and what we want to do, we will find the way to do it.

Brands may be recognized by various elements, among which we can enumerate for example: name and advertising slogan, logo and corporate identity, website, social media, blog, online advertising or public relations activities. Name is one of the most important elements which affect the brand communication. Advertising slogan is an equally essential element, which is an extension of the idea carried by the name. It should refer to it directly or have explanatory function. The logo, as a sign, is one of the most tangible effects of branding. It is remembered better than words, used to identify products and to encode the message (it expresses the characteristics of the brand). The logo has to be consistent with other elements of corporate identity. Corporate identity shall be understood as all possible graphic designs, the use of which affects the brand development in the awareness of consumers. Examples include business cards, graphic illustrations, photos, video clips, folders, and banner advertisements. Website is another branding tool, and it serves as a company's showcase. In the case of furniture companies, websites should enable browsing full range of products and services. A key element in creating a website is the dialogue with customers through dedicated discussion forums or comment systems. Currently, social networks are very popular with consumers who look for information about a given company and about products [Branding – budowanie świadomości marki w Internecie]. They enable faster contact of customer with seller and up-to-date information on current promotions and events. In addition to running websites and fan pages in social networks, activities which are aimed at ranking high in the Google search engine are also very important. Google AdWords sponsored links and SEO (Search Engine Optimization) are used most commonly. The former is characterized by providing the ability to quickly reach specific target groups, by low costs of campaign, and, what is important, the fees are charged only for effects. SEO is a long-term process and it's much more expensive, but it is more effective in the long run than sponsored links [Linki sponsorowane AdWords czy pozycjonowanie]. A large role in effective SEO is also played by blogs and content marketing, based on creating interesting and unique content that helps to attract potential customers [Content marketing,
czyli z miłości do jakości]. In case of the furniture industry, there are many issues and tips that may prove useful for a consumer: from interior design and selection of appropriate components to furniture care. In addition to corporate identity and marketing on the Internet, public relations tools are also worth using. They may take the form of meetings on trade fairs, inviting customers to company headquarters ("open days"), publication of press releases describing the latest changes in the structure of the enterprise or announcements of a new product. These and other aspects influence the increased interest and trust of customers and business partners to a given brand and allow them to get to know it better. [Branding – budowanie świadomości marki w internecie].

To sum up, branding is a long-term and complex process, which comprises using a number of tools in order to distinguish a given brand from its competitors and make it permanently embedded in consumers’ minds. Therefore, the latter part of this article presents a study on current branding activities of the Polish furniture enterprises.

**METHODOLOGY**

The studies have been carried out with the use of the questionnaire survey, published on the Internet from 02.11.16 to 31.01.17. During this period, answers were provided by 150 respondents. The questionnaire survey was divided into 2 groups of questions: personal data regarding: age, gender, place of residence and the income of respondents and a group of questions about the branding of Polish furniture brands. The second group of questions consisted mainly of closed-ended questions and some semi-open-ended ones. Mainly cafeteria multiple choice questions were applied in order not to limit respondents to provide only one answer. They also had the possibility to add their own answers. Two questions were of the Likert-type scale, to measure the attitudes of respondents to specific branding tools.

**RESULTS**

Women accounted for 63% of the survey respondents. The respondents were divided into 5 age groups. Most people were between 18-25 years old (41%). The second largest group comprised people between 26-30 years old (16%). Each of the two groups of people between 31-40 years old and between 41-50 years old, comprised 15% of the respondents. The smallest group of respondents comprised people of over 50 years of age (13%). The most common place of residence proved to be a big city (52%), followed by: village (19%), medium-sized town (18%) and small town (11%). Respondents also stated the amount of average monthly net income (PLN) at their households. Because of the even distribution of the answers to this question, they are not deemed relevant in the study.

In the first question, the respondents were asked about who makes decisions about buying furniture in their household. Its purpose was to determine the gender, to which branding activities should be targeted. This is an important aspect when arranging company stores, designing ads or organising promotions. The research showed that as many as 53% of people take decisions jointly, and in 43% of cases women decide on their own. Men accounted for just 4% of decision makers (Figure 1). It follows that Polish furniture makers should use universal branding, creating comprehensive, family arrangements.
The second question concerned the recognition of Polish furniture brands by the respondents. Its purpose was to verify knowledge about a given brand based on the gender of respondents. It considered 10 furniture brands which produce cabinet furniture, both of wood and wood-based materials, and which belong to different price segments. Respondents were asked to assign ratings 1-5 to each of them (1 – I do not know at all, 5 – I know very well). Black Red White (BRW) turned out to be the most famous brand. 128 respondents declared that they know it very well or well (80% of women and 94% of men). Not a single person declared that they do not know this brand. The Bodzio company turned out be very well-known as well (43 votes – I know very well, 50 votes – I know). Next in terms of visibility were Forte, Vox and Kler companies. Mebin brand took the last place, receiving 123 votes claiming that they do not know this brand at all (81% of women and 83% of men), only 1 voice – I know and 2 votes – I know very well. Results confirm the universality of branding strategies of furniture brands, as both women and men, indicated the same manufacturers (Figures 2 and 3). High awareness of BRW and Bodzio furniture, is probably affected by their extensive distribution network (BRW furniture can be found in nearly 1000 stores throughout the country), their own company stores (BRW – nearly 80 stores, Bodzio – 320) and advertising on the television, the radio or the Internet.
Another question was to indicate the brand, the logo of which is frequently seen by respondents in public space. 145 respondents indicated Black Red White (BRW) brand, followed by: Bodzio (83 votes), Forte (58 votes) and Vox (57 votes) (Figure 4). By analysing the responses, it can be easily noted that the most common logos belong to the same brands that are best recognized by respondents, hence the conclusion – more visible corporate logo in public space significantly affects the recognition of a given brand. Next question allowed to determine which places are most effective for building brand awareness.

Respondents declared where do they see logos of furniture companies most often. It appeared that such places were furniture stores and retail stores (98 votes) as well as billboards and advertisements on cars etc. – 82 votes. Fewer respondents chose media (Figure 5) as probably the furniture industry advertisements are not sufficiently visible in relation to other television commercials. This confirms that it is very important for furniture manufacturers to have their own furniture stores. The larger the distribution network is, the more common are commercial vehicles covered with advertisements or billboards with current promotions.
Answers to the next question were to demonstrate where do customers look for information on furniture. Catalogues and promotional leaflets (94 replies), furniture stores (78 votes), and the websites of a given brand (74 votes) turned out to be the most common (Figure 6). According to the research, manufacturers, in addition to taking care of the appearance of the furniture stores, should provide high availability of printed informative and promotional materials, as well as the attractiveness of websites, which allow buyers to get acquainted with products on offer without leaving their home. But it is necessary to bear in mind that the first two positions are targeted to users from all age groups, while in the case of websites, the frequency of choosing them decreased with the increasing age of respondents – 53% of respondents were at the age between 18-26 years old, and only 1% were over 50 years old (Figure 7).
Next, the respondents were asked to declare whether the quality of a furniture brand website affects their opinion on it. Most people responded as "Yes" (36%) and "Rather Yes" (24%) (Figure 8). In view of the above, it can be concluded that, in the case of furniture brands, website and its skillful handling is an important branding tool.

In the next question, respondents were asked if they could indicate which of the furniture brands have Social Media, for example, Facebook or Instagram. Answers to this question were to determine consumer awareness about the activity of furniture brands in social media. Surprisingly large number of people (111) responded that they could not indicate such brand and were not interested in that. From the indicated entities Black Red White received the most votes (33) (Figure 9), which highlights its recognisability by consumers even more. This brand has numerous profiles in social networks, such as: Facebook (over 200 600 "likes"), Instagram (11 000 followers), YouTube (over 3 000 subscriptions, viewed hundreds of thousands of times) and slightly less popular Pinterest and Google+. In addition to the above, on their website there is also a link to the blog. If we go directly to the company's channel on YouTube, we will see a suggestion to subscribe and a film with the latest advertisement. We can also familiarise with the BRW's furniture offer by means of a free application. However, most of the answers indicate that, customers rarely keep track of furniture brands' social networking sites. Therefore it should be considered in which direction should furniture brands go. Should they increase the quality
of branding activities in this respect and follow Black Red White, which is the leader, or should they give up on Social Media, due to their little popularity among buyers.

The last question of the questionnaire concerned furniture brands' blogs, and more specifically, the frequency of reading them by respondents. Most respondents do not read them at all (78%), 17% of people read them several times a year, and only 3% do it more than once a month (Figure 10). We can therefore see a clear lack of interest in this branding tool among the customers of Polish furniture brands. This may result from the lack of time of the surveyed people to track this source of information and inspiration, or from the way of running such blogs, which needs to be improved.

![Figure 9](image9.png)

**Figure 9.** Could you indicate which of the furniture brands have social media, for example, Facebook or Instagram? If yes, please mark them. (Source: own research)

![Figure 10](image10.png)

**Figure 10.** How often do you read the furniture brands' blogs? (Source: own research)
SUMMARY
The study considered 10 Polish manufacturers of cabinet furniture. By analysing the results, we can conclude that Black Red White brand is the most recognisable one, leading the most effective branding activities. It relies on a wide range of furniture and accessories, enables ordering products via the Internet, offers transport, carrying and assembling of their furniture. Although it is in the third position in the Ranking of Furniture Manufacturers 2016, after Forte and Wójcik furniture factories, it has a strong competitive position and is a model to follow in terms of branding strategy. From the answers of the interviewees, it can be concluded that furniture brand recognition is mainly affected by extensive distribution network of a given brand. Customers preferably visit official stores and pay attention to advertising in public space. They look for information about the offered furniture in catalogues and promotional leaflets, as well as on official websites, the high quality of which, has a positive effect on the brand. Polish people use various social networks, which are becoming more and more popular marketing tool for furniture brands.

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The use of websites in the process of furniture sales in Poland

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Abstract: The use of websites in the process of furniture sales in Poland. This article is an attempt to answer the question whether Polish consumers purchase products of the furniture industry via the Internet. In order to achieve this, a questionnaire survey was conducted and the survey was completed by 150 people. The study focused also on problems noticed by consumers in connection with the Internet sales, and on ways to encourage them to more frequent purchases with the use of this form of distribution. The results of the study show that more than half of the respondents purchased furniture over the Internet at least once. Problems, which they indicated most often concerned inability to see the product before the purchase and fear that a product would not be compliant with its description. Among factors encouraging to online shopping, respondents most often mentioned lower product and delivery costs.

Keywords: e-commerce, online sales of furniture

INTRODUCTION

E-commerce is a process of selling and buying products, that is the conclusion of commercial transactions, by electronic means via the Internet [Gregor, Stawiszyński, 2002]. What is important, each transaction carried out via the electronic network is the result of four stages – search, order, payment and delivery [Szpringer, 2000]. The definition comprises the aspect of delivery, which, in most cases, is carried out by traditional transportation. Therefore, a distinction is made between two models of e-commerce: "pure" and "mixed" [Żurak-Owczarek, 2011]. The "pure" model of e-commerce means buying a product or service in a digital form (e.g. e-book). Its delivery to a customer and transaction processing also have digital (electronic) nature. If one of these elements takes the physical form, we talk about a "mixed" type of e-commerce. Thus, in the case of online sales of furniture, we are dealing with the mixed model.

37% of Polish Internet users who shop online, declare that they bought furniture industry products via the Internet (Figure 1). According to data of the B+R Studio, it is estimated that in 2016 over 202 000 online furniture purchases were made. This represents 6% of all retail transactions concerning the purchase of furniture. In the analysis of the declared expenditures on furniture purchased via the Internet, B+R Studio estimated the average value of PLN 713, however, the value of the vast majority of purchases was lower than PLN 500 [Coraz częściej kupujemy meble przez Internet].
Figure 1. Online shopping (source: E-commerce w Polsce 2016)

We can observe a strong development of e-commerce on the Polish market in the furniture industry. In February 2017, IKEA Industry Group, in connection with a great interest in this form of distribution, have introduced online shopping in the territory of Poland. "Internet shopping" service is now available in all the cities, in which there is an IKEA store in the surrounding area and the supply area will be extended [Rozwój meblowej sieci sprzedaży w 2016 roku]. The Swedish giant will certainly be followed by a whole group of Polish producers aspiring to be the leader, and who have omitted this distribution branch until now. However, significant prices may unfortunately prove to be a problem, as in case of the IKEA company, they currently start from the amount of PLN 139. This may limit the profitability of purchases in case of contracts of lower value.

METHODOLOGY

In order to obtain information on the subject of this work, a questionnaire survey was conducted. It was published on the Internet from 01.11.16 to 10.01.17. Answers of respondents came also directly (paper form of the questionnaire) from people visiting the Jupiter Centum furniture gallery in Warsaw. It was decided to obtain part of the responses with the use of the direct method, in order to learn as much as possible about the aspects which discourage clients from purchasing via the Internet. During the period of the study,
responses from 150 people were collected. The questionnaire survey consisted of 10 questions divided into two groups:

I – personal information – gender, age, place of residence, net monthly income in the household

II – questions about the frequency of online purchases, type of furniture bought over the Internet and aspects which encourage to and discourage from the purchase of furniture over the Internet.

The second part of the questionnaire consisted largely of the questions in the form of cafeteria. There were used both single-choice, close-ended questions, and multiple choice, semi-open-ended questions in order to enable respondents to provide multiple answers and use the "other" option (own answer). The last question in the questionnaire had an open-ended form, in order to enable the respondents the opportunity to indicate aspects which may have been omitted by the author of the study.

RESULTS

According to the replies, the surveyed group consisted in 61% of women (Figure 2). Respondents were divided into 5 age groups: 18-25 years old, 26-30 years old, 31-40 years old, 41-50 years old, and over 50 years old. Most of them turned out to be between 18 and 25 years old (37%). The second largest group comprised people between 26 and 30 years old (19%), followed by groups of (17%) 31-40 years old, (14%) over 50 years old and (13%) 41-50 (Figure 3).

The most common place of residence proved to be a big city (55%), followed by: medium-sized town (19%), village (15%) and small town (11%) (Figure 4). The respondents were also asked to declare net income per one person in their household. The distribution of answers to this question was fairly even (Figure 5).

In the first question of the second part of the questionnaire, respondents were asked how often do they shop online. This question was asked in order to outline general interest in the e-commerce market, regardless of the type of purchased products. The largest part of respondents (41%) declared that on average they shop online several times a year. The following answers were respectively "about once a month" – 27%, and "over once a month" – 22%. Only 10% of respondents declared that they do not use this purchase form at all (Figure 6).
Based on the results, it was noted that in villages and small towns there is the lowest percentage of people who have never shopped online (4.3% and 5.9%) (Figure 7). What is more, among those living in villages, there is the highest percentage (34.8%) of people who declared to do online shopping more often than once a month.
A group of people who declared that they do not shop online consisted, in over 73%, of people aged over 41, however, this does not mean that people over that age are not interested in this form of transactions at all. Near 62% declared that they shop online at least a few times a year.

In the second question, the respondents were asked how often do they shop online once again, however, this time they were directed specifically to the furniture industry. Among all the respondents only 28% declared that they purchased furniture online many times. Considering the nature of the product, that is a piece of furniture, it shall be noted that in most cases there is no need to do such purchases frequently. One product should work well for at least a few years. If we add the responses of people who declared a single purchase of furniture over the Internet, we will receive 52% of respondents. The remaining 48% of respondents declared that they have never bought furniture in such way (Figure 8).

Figure 8. Have you ever bought furniture over the Internet? (source: own research)

Answers to the following question were supposed to reveal the most frequent aspects which discourage people from the purchase of furniture over the Internet. The most popular aspect chosen by 119 respondents was the inability to see the product. The second reason, with the number of 74 respondents, was the fear that a product would not be compliant with its description. Other aspects indicated by respondents comprised high prices of delivery (51 replies), fear of damage during transport (47 replies) and insufficient description of furniture (38 replies) (Figure 9).

Figure 9. What aspects discourage you from purchasing furniture over the Internet? (source: own research)
We can therefore see that the biggest problem is the lack of a tangible contact with products and low level of consumer trust to manufacturers.

Next two questions were addressed only to people who have already bought furniture over the Internet in the past (78 respondents). First of them regarded the type of furniture that those people have bought. The most popular type (53 replies) turned out to be "chairs, tables, shelves, cabinets, etc.". The second popular option (44 replies) was "wardrobes, tables, beds, sofas, etc." (Figure 10). Sets of furniture and kitchen annexes were chosen only by 14 people.

![Figure 10. What types of products from the furniture industry did you buy over the Internet? (source: own research)](chart10)

By analysing the results, we can see that most customers decide to purchase furniture over the Internet if a given product is of small size. Probably this is mainly due to relatively low price and thus lower "risk" in case the product turns out not to be compliant with its description.

The next question was addressed to people who bought a piece of furniture online, and concerned directly the reasons why they have decided on this type of shopping. Most popular response in this case was the lower price, which was chosen by 60 people (77%) and time saving (58 replies). A significant part of respondents (34 replies) indicated also convenience of this form of shopping, and a large selection of products (30 responses) (Figure 11).

According to the Gemius study conducted for e-Commerce Polska, the answers to the above question seem to confirm the great importance of low prices of products available in online shops as well as the convenience and time savings. It can be seen that even trust to a given brand in confrontation with advantageous prices, in most cases, will not be recognised by consumers as a priority.
The last question in the questionnaire had an open-ended form. Respondents were asked to make their own suggestions of ways which would encourage them to buy furniture online more often. Answers were provided by 128 people. Due to frequent repetition of the respondents' ideas, they have been presented as the most popular categories in the form of a chart. (Figure 12).

Answers of the respondents reveal the most frequent one, that is the lower final price of products (36 replies) and its delivery (26 replies). Part of the respondents (23 people) did not see any way which would encourage them to buy furniture online. Unfortunately, they have not explained if this is due to prejudices, bad experiences or other reasons. Other aspects were "more accurate photos" and "better descriptions of furniture" with 17 and 16 replies respectively. Several respondents (8 replies) indicated the issue of free returns in case of deficiencies or damage, and on the visual representation of furniture in the three-dimensional form (6 replies).
SUMMARY

The study revealed that the majority of consumers have bought furniture online at least once. The vast majority of respondents see some problems with this form of distribution, which entrepreneurs have to face in order for the Internet to become a popular place to buy furniture. The most significant problems comprise inability to see the product before the purchase and fear that a product would not be compliant with its description. However, there are already several strong furniture industry representatives on the Polish Internet: Black Red White, VOX, Kler, and more recently, the aforementioned IKEA. But many important "players" of this business, do not offer such form of purchase, which is certainly a good chance to increase profits from retail sales in Poland, especially considering the Act of 1 September 2016 introducing the tax on retail sales in brick and mortar shops [Sklepy Internetowe bez podatku od sprzedaży detalicznej].

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Comparison of selected physical and mechanical properties of wet archaeological wood from the Neolithic age in the different restoration methods

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Abstract: Comparison of selected physical and mechanical properties of wet archaeological wood from the Neolithic age in the different restoration methods. A specific characteristic of archaeological wood is its level of biodegradability. Tests were performed on a sample of wet archaeological wood from the Neolithic age. Three conservation methods were used in this work: impregnation solution of PEG 400, solution of sugar and lyophilisation. The humidity, colour, density, volume shrinkage and Brinell hardness of the wood were determined.

Keywords: restoration of wed wood, polyglycol solution, sugar solution, lyophilisation, alder wood, density, Brinell hardness.

INTRODUCTION

Archaeological wood is defined by some as wood used by ancient cultures and which stayed in specific natural conditions [Florian 1990, Krajewski, Królikowska-Pataraja 2005]. The conditions in which the wood remained have great impact on the character of the conservation processes. Without conservation wet archaeological wood looses its moisture content and its form and dimensions change drastically. Today, there are three most often used methods of conservation to save archaeological finds; these are: saturation with a polyglycol solution, saturation with a sugar solution or lyophilisation.

The purpose of this work was to compare the methods currently used in the conservation of wet archaeological wood. The comparison was made on the basis of physical characteristics (density) and mechanical characteristics (hardness by Brinell method) of wood after the conservation process. This research will allow us to determine an optimal method for the conservation of wet archaeological wood from the Neolithic age.

Methods of conservation of wet archaeological wood used today

A specific characteristic of archaeological wood is its level of biodegradability. Among the properties which allow us to assess the state of object’s preservation is the loss of wood mass, which may range from 15% to 65%, depending on wood species [Babiński 2005]. Due to advanced stage of degradation after recovery, such wood must undergo conservation procedures, including structural strengthening procedures. For a number of years a variety of natural and synthetic substances have been used to consolidate wood or only to slow down the process of moisture evaporation.

Among the substances widely used in the conservation of wet archaeological wood were polyglycol (polyethylene oxide, polyoxy ethylene, PEG) [Ważny, Kurpik 2005] – a chemical substance whose chemical formula is HO(C₂H₄O)nH. It was invented by French scientist Carl Adolph Wurtz in 1895 [Rowell, Barbour 1990]. As a polymer from the polyether group, polyglycol is non-ionic, hygroscopic, and most of all, water-soluble, which means that artefact conservation becomes reversible. PEG also dissolves in alcohols. But
because water is a much cheaper solvent, it is used much more often [Hamilton 2000]. PEG used in the conservation process has molecular mass of 400 (in liquid state). PEG with the molecular mass of 1000-15000 is in the semi-liquid state and has the consistency of vaseline. PEG of a higher molecular mass (3250-6000) is wax-like. The method of using PEG was the first reliable but also inexpensive [Hocker, Almkvist, Sahlesdt 2012]. It was also fairly easy to carry out [Hamilton 1997]. A new direction in the conservation process is the use of PEG of molecular mass 200 and 2000. A good example of this is the secondary conservation of Mary Rose [Preston et al. 2014].

One of the drawbacks of this method is that it is very time-consuming. The conservation of a Swedish boat from the 17th century took 25 years [Rowell, Barbour 1990]. Another problem posed by PEG solution is its effect on the corrosion of metal [Gourbeyere, Guilminot, Dalard 2003, Giorgi, Chelazzi and Baglioni 2006]. On the other hand, an important advantage of PEG is that it is resistant to microorganisms [Hocker and others 2012].

More popular and cheaper is the sugar method which, thanks to the use do saccharides (beet sugar, manitol, sorbitol), results in dimensional stabilization of archaeological wood. In comparison to PEG, sugar is a readily available and inexpensive substance. The advantage of the use of saccharides is that their particles are of the same size as those of PEG. Sugar is capable of easily penetrating wood and is much less hydroscopic than PEG [Hamilton 2000]. As shown by the results of performed conservations, wood retains its original colour after such a procedure [Królikowska-Pataraja, Ważny 1999]. A drawback of this method, however, is the susceptibility of the processed artefacts to organisms which would attack those objects as food. In such case in particular, solutions used in the conservation of archaeological wood should be enriched with biocide.

Lyophilisation (freeze drying) consists of removing water from wet wood without causing any significant changes in the appearance, shape or dimensions of the object. This method has been in use for 25 years [Jagielska 2004]. Prior to freezing, wood is kept in an aqueous polyethylene oxide solution (with low degree of polymerization – PEG 400). This procedure is used to strengthen the structure of the artefact and to avoid cracking at the initial stage of lyophilisation [Ambrose 1990]. After it is soaked in the PEG solution, the wood is frozen to a temperature of -26˚C at the initial phase [Dyrka 1999]. Next, the object is transferred to a device where sublimation occurs. After lyophilisation the object is light, does not change its colour and, what’s most important, this method is reversible.

MATERIALS AND METHODS

Tests were performed on a sample excavated at the end of July 2007 during archaeological excavations in Warmińsko-Mazurskie Voivodeship. The Institute of Archaeology of the Warsaw University was carrying out excavations of a Neolithic settlement there. The soil at the excavation site was characterised with a relatively high moisture content, low oxygen access and acidic pH. Having been excavated, the artefacts were stored in plastic bags. The archaeologists tried to maintain relatively high moisture content of the artefacts, comparable to that of the turf soil in which they had been buried. The tested artefact consisted of a number of fragments of a wooden club. The length of the object was 205mm and its width was 4mm (Fig. 1). Due to the advanced stage of degradation of the wood tissue, the wood grain was not visible. It is likely that the object was made of a diffuse-porous wood. The wood had dark brown colour with lighter spots. The object could be crushed with fingers, thus its strength can be assessed as close to zero.
Preservatives
The following substances were used in conservation of the object:
- PEG 400 with low molecular mass in the form of a viscous liquid, with low toxicity, colourless, water-soluble and poorly soluble in aliphatic carbohydrates (nr CAS: 25322-68-3).
- PEG 4000 with high molecular mass is a white wax-like substance (nr CAS: 25322-68-3).
- Beet sugar: solid, crystalline, colourless, sweet to the taste, non-toxic, very soluble in water, sucrose particle built of α-glucose and β-fructose particles bound with 1,2-glucosidic linkage.
- 10% solution of 4,5-dichloro-2-octyl-isothiazolone (nr CAS: 64359-81-5), biocide based on quaternary ammonium compounds.

Description of the experimental part
In order to determine the wood species the artefact was made of, several thin pieces were taken as samples from three anatomical directions of the wood: tangential, radial and longitudinal. The samples were kept in a solution of alcohol, water and glycerine for 24 hours and then cut using a microtome. The obtained pieces of wood were used to create microscopic sections.

The samples used in other tests were cylindrical in shape and were 15mm along the fibres and 30 mm in diameter. Three samples were used for each of the aforementioned conservation methods.

The humidity, density and volume shrinkage of the samples were determined using the standard method described by Kozakiewicz [2006]. Wood density before conservation was stereometrically determined in absolutely dry state. After conservation the samples were aged in laboratory conditions for 3 weeks, and then their density and Brinell hardness at humidity of 12% was determined.

Wood conservation methods
Conservation using PEG. The conservation started with the impregnation of archaeological wood samples with a 5% solution of PEG 400. The concentration of the PEG 400 solution was uniformly increased by 2.5% every 4 months up to 40%. Next, a 40% solution of PEG 400 [Hoffman 1986] was prepared in which the samples were kept for 2 months.
Conservation using sugar. Conservation with sugar started with a 1% solution, maintaining the temperature of 60°C in a water bath [Jagielska 2005]. Over 6 months, the solution concentration was being increased by 2% everyday, up to the maximum value of 50%. To each of the solutions 10ml (per litre of the solution) of biocide was added.
Conservation using lyophilisation. Prior to lyophilisation, the samples were bathed in a 10% solution of PEG 400 [Jagielska 2004] at the atmospheric pressure and ambient temperature of about 20% for 1 month. Next, the samples were frozen at a temperature of -20°C and then sublimated at 10mBar, -56°C.

RESULTS AND ANALYSIS
Microscope examinations of the preparations made from archaeological wood samples were performed in light penetrating at x10 and x40 magnifications (Fig. 2). The examinations show that it is a diffuse-porous wood. In the transverse section, we can see single vessels and clusters consisting of up to 7 vessels. In the radial section, we can see a ladder perforation of the vessels. In the tangential section, we can see single-row radii of up to 23 cells in height. It was concluded that the tested wood is alder (*Alnus sp.*). The wood of freshly-felled alder is light, soft, cleavable and fragile in the air but considered very sturdy in water [Krzysik 1970].

![Micrographs of alder wood](image)

**FIG.2.** micrographs of alder wood a) radial section, b) tangential section

Moisture content in the sample was very high, which points to a very high degree of wood degradation. As much as 81.8% of the sample mass consisted of water, thus the absolute moisture of the tested archaeological wood was 469%.

<table>
<thead>
<tr>
<th></th>
<th>Density (at W=12%)</th>
<th>Brinell hardness</th>
<th>Colour</th>
</tr>
</thead>
<tbody>
<tr>
<td>Prior to conservation</td>
<td>-</td>
<td>-</td>
<td>Dark brown</td>
</tr>
<tr>
<td>PEG</td>
<td>940</td>
<td>21</td>
<td>Dark brown</td>
</tr>
<tr>
<td>Sugar</td>
<td>1000</td>
<td>30</td>
<td>Dark brown</td>
</tr>
<tr>
<td>Freeze-dried</td>
<td>160</td>
<td>22</td>
<td>Light brown</td>
</tr>
<tr>
<td>No conservation</td>
<td>150</td>
<td>0</td>
<td>Grey</td>
</tr>
</tbody>
</table>

Density of the control sample, i.e. a sample which did not undergo any conservation, was 150kg/m³. In comparison, density of air-dry alder is within 490 and 640kg/m³, and 550kg/m³ on average [Krzysik 1970]). Therefore, the tested sample of Neolithic wood had over 3.5 times lower density than contemporary alder wood. Worth noticing are the densities of the samples after PEG and sugar conservations.
The samples conserved with PEG solution and sugar differ only slightly; they both were around 1000kg/m$^3$. Thus, archaeological wood conserved with those substances showed density six times higher than that of the control samples. Samples which underwent lyophilisation with a prior bath in low-molecular PEG reached only a marginally higher density than that of the control samples.

Samples conserved with sugar solution showed the highest hardness, comparable to that of contemporary wood. Contemporary wood hardness, determined with the Brinell method, is 33–38MPa. Samples conserved with PEG solutions and samples which underwent lyophilisation after a bath in low-molecular PEG showed comparable hardness, lower than the hardness of samples conserved with the sugar method. However, lyophilisation can’t always be used. According to Jagielska [2010], during the conservation of some antiques, one lyophilised element began to peel and almost the entire paint layer separated from wood. Thus, there is a need to further test and perfect the methods of conservation of wet archaeological wood using lyophilisation.

CONCLUSIONS

Samples conserved by lyophilisation with a prior bath in a low-molecular PEG solution obtained light, natural colour. The samples treated with PEG and sugar turned darker in colour.

Samples treated with both solutions reached very high density, thus they substantially increased in mass. It is different in case of the lyophilised wood. The samples which underwent this method reached a mass four times lower than the samples used in the other methods discussed here.

The samples of wet archaeological wood which underwent conservation with the sugar method showed higher hardness than the samples treated with PEG. Comparing those results with the results for contemporary wood, it is clear that the differences are very little. But when we take into consideration the state of degradation of the samples or their possible destination, the hardness value will be very important for further use of such an object.

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Streszczenie: Porównanie wybranych właściwości fizycznych i mechanicznych mokrego drewna archeologicznego z epoki neolitu po procesie konserwacji różnymi metodami. Drewno ma szansę przetrwać przed długi czas w środowisku suchym lub mokrym (np. w głębszych warstwach wilgotnej gleby). Niestety nawet w takich warunkach zachodzi szereg zwykle powolnych procesów zmieniających jego strukturę i właściwości. Częściowo zdegradowane drewno archeologiczne wymyka się mokrego środowiska zwykle przy wysychaniu ulega silnemu skurczowi, pękaniu i deformacji. W niniejszej pracy badaniom poddano archeologiczne drewno olszy z epoki neolitu stosując trzy metody konserwacji: nasycanie roztworem poliglikolu, nasycanie roztworem cukru oraz liofilizację. We wszystkich przypadkach zabiegi konserwacji okazały się skutecznymi w zapobieganiu deformacji i drastycznym zmianom wymiarowym silnie zdegradowanego drewna archeologicznego przy przejściu ze stanu mokrego w suchy. Zakonserwowane drewno charakteryzowało się wysoką gęstością i twardością porównywalną ze współczesnym drewnem olszy.
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