Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology No 90, 2015: 119-126
(Ann. WULS - SGGW, For. and Wood Technol., 90, 2015)

Mechanical and physical properties of plywood made of unmodified and thermally modified veneers

DOMINIKA MATUSZEWSKA, MAREK GRZEŚKIEWICZ
Department of Technology and Entrepreneurship in Woodworking Industry, Warsaw University of Life Sciences – SGGW

Abstract: *Mechanical and physical properties of plywood made of unmodified and thermally modified veneers.* The beech veneers were thermally modified in laboratory conditions (170^{o}C; 3 hours). Plywood was made of unmodified and thermally modified veneers. Unmodified and thermally modified veneers were use to made 9-layers plywood. The unmodified veneers were the outer layers of plywood. Plywood panels were made in industrial conditions using UF resin. A part of plywood was also subjected to artificial aging in laboratory conditions. The MOE, MOR and hardness samples made of plywood were determined according to the PN-EN standards. Overall plywood swelling and water absorption were determined. The addition of thermally modified veneers causes decrease in MOE and reduce plywood swelling and water absorption.

Keywords: plywood, thermal modification, veneer, beech, artificial wood ageing

INTRODUCTION

In Europe, different varieties of wood thermal modification process are more widely used. They are aimed at improving natural characteristics of wood. Thermal modification of wood increases its dimensional stability and reduces its equilibrium moisture content. In addition, thermally modified wood has higher resistance to biotic factors and different colour, which is similar to the colour of dark exotic species.

For several years, process of thermal modification is used not only to change properties of solid wood, but also for veneers. In 2008, trials of veneer modifying started in Poland. Thermally modified veneers can be used for veneering furniture items, doors and skirting boards. First thermal modification processes in industrial environment are being conducted in Poland. Research aimed at finding new opportunities for applications of thermally modified veneers are undertaken (***Grześkiewicz, Laskowska, 2010***). Plywood from beech veneers was made under laboratory conditions with the use of UE resin, PF resin and PE as a bonding agent (***Grześkiewicz et al., 2009***). As a result of research, a significant improvement in relations between the properties of plywood to water at reduced mechanical properties, depending on the intensity of the modification of veneers was revealed.

Resistance of the thermally modified wood to prolonged exposure to external factors (such as: precipitation, solar radiation and temperature fluctuations) is an important aspect. Studying the impact of aforementioned factors on the characteristics of plywood would be time consuming and would require even decades. Artificial aging process gives us the opportunity to examine material in the accelerated way, which takes place under laboratory conditions and the results allow predicting the behaviour of the wood due to natural aging process. Artificial aging process involves intense factors such as temperature, increased or decreased relative air humidity, UV radiation, which has an impact on changing the properties of wood (***Jankowska, 2010***).

RESEARCH OBJECTIVE

The aim of the study was to determine the influence of the addition of thermally modified beech veneers for plywood on its selected physical and mechanical properties such as MOR, MOE, Brinell hardness, swelling and water absorption as well as impact of artificial aging of the plywood on these properties.

MATERIAL AND METHODS

The material used for tests were samples obtained from two kinds of plywood made in industrial conditions. The first type of plywood was 9 - layer plywood obtained from non-modified veneers only. The second type of plywood was 9 - layer plywood produced from thermally modified and non-modified veneers, in which the outer layers were thermally non-modified veneers (plywood hereinafter referred to as "mixed"). Veneer used for plywood belonged to 1^{st} quality class. Thermal modification of veneers in the overheated steam has been performed under laboratory conditions. The strict process of veneers thermal modification took approx. 23 hours.

For the production of all factory plywood beech veneers and urea-formaldehyde resin (from Lerg) were used. Hardener used in the research is the Swedish company hardener, Casco 2545

Parameters of plywood pressing were as follows:

- temperature of pressing: 100-110 ^{o}C,
- pressing time: 1 min / 1mm thickness of the board,
- pressure: 1.6 MPa.

In addition, half of plywood, both thermally non-modified and "mixed" were subjected to artificial aging in a climatic chamber according to ASTM D 1037: 1999 procedure.

Determination of static bending strength and modulus of elasticity were performed according to EN 310: 1993 " Wood-based panels: Determination of modulus of elasticity in bending and of bending strength". Determination of Brinell hardness was based on the PN-EN 1534: 2011 "Wood and parquet flooring. Determination of resistance to indentation (Brinell). Test method". The Brinell hardness test used the same samples, which were later used to determine the linear swelling. Determination of linear swelling is based on the PN-D-04230: 1968 "Plywood. Determination of linear swelling" and on own procedure. Determination of water absorption was performed according to PN-D-04226: 1968 "Plywood. Determination of hygroscopicity".

RESEARCH RESULTS

The test results of the static bending modulus of elasticity (MOE) are shown in Figure 1. The conducted research allows to conclude, that plywood tensiled along the fibres obtained almost twice as high MOE values. Use of thermally modified veneers decreases the MOE values of plywood bent along and across the fibres of plywood in comparison to control board. Artificial aging process also influenced the decrease in the MOE value.

Analysis of Kolmogorov-Smirnov test showed that variables related to the modulus of elasticity and the static bending strength deviate from normal distribution. However, considering large sample, skewness and kurtosis close to zero it can be stated that use of parametric tests with statistical data analysis will be entitled. In order to check whether the type of plywood differentiate the static bending modulus of elasticity, Student's t-test for independent samples was performed. The analysis showed significant differences in the MOE values along and across the fibres, between non-modified and "mixed" plywood, either subjected and not treated with artificial aging process. Artificial aging process significantly affects the modulus of elasticity. Only analysis of the control plywood bent along the fibres, both artificially aged and not treated with that process, showed no significant differences in elastic modulus.

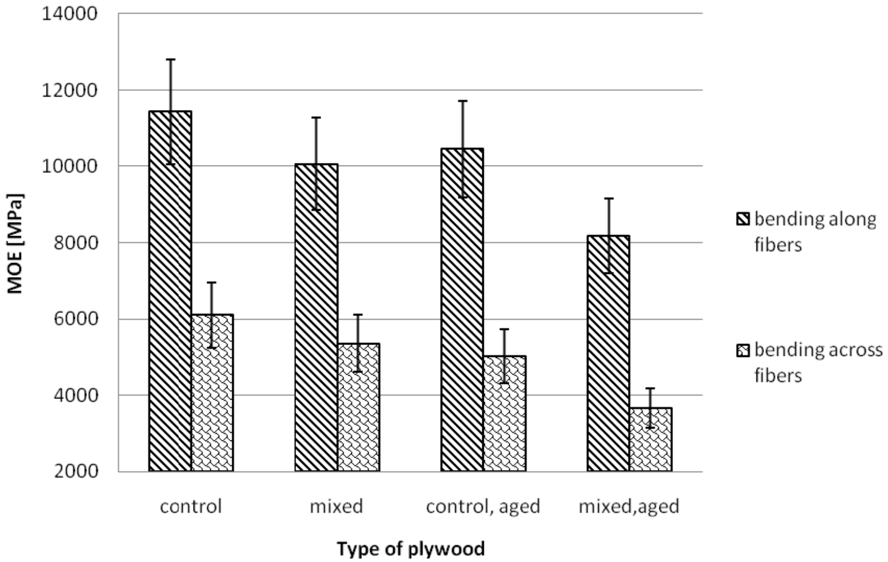

Fig. 1 Static bending modulus of elasticity (MOE) of all types of plywood, according to the fibres direction in the outer layers, with respect to the long edge of the sample

Summary of the static bending strength (MOR), depending on the fibres direction in the outer layers of the plywood to the long edge of the samples, is shown in Figure 2. For each type of plywood, those with parallel direction of the fibres of the outer layers with respect to the long edge have a higher strength. In the case of "mixed" plywood and artificially aged "mixed" plywood strength value is almost twice the size in the case of bending along the fibres. Use of thermally modified veneers to manufacture of plywood influences the change in bending strength value, when compared to non-modified plywood. However, this change is not obvious. The addition of thermally modified veneers increases the bending strength along the fibres, while reducing the bending strength across the fibres. Artificial aging of plywood causes a decrease in the static bending strength.

To verify whether the type of plywood influences the change of static bending strength, Student's t-test for independent samples was performed. The analysis showed insignificant differences in average values of strength of control plywood and "mixed" plywood bent along the fibres, while significant differences in the case of bending across the fibres for non-artificially aged plywood and statistically significant differences in the case of bending for both, along and across the fibres for plywood subjected to artificial aging process. Artificial aging process results in a statistically significant change in average static bending strength for both control plywood and the "mixed" plywood.

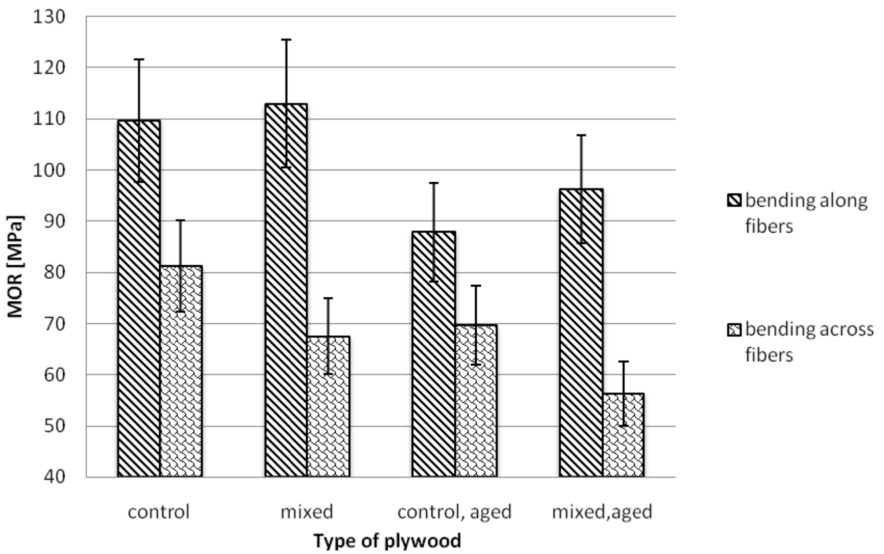

Fig. 2 Static bending strength (MOR) of all types of plywood, according to the fibres direction in the outer layers, with respect to the long edge of the sample

Hardness. Average hardness values are presented in Figure 3 Use of thermally modified veneers to production of plywood does not affect the hardness unambiguously. Data concerning plywood, which was not subjected to artificial aging process shows, that the hardness of the samples remained unchanged for the samples of "mixed" plywood, however, in the case of the artificially aged samples, "mixed" plywood is characterized with lower hardness than the non-modified plywood. Artificial aging process has no significant influence on the hardness of plywood. The hardness values are slightly lower for the artificially aged plywood.

Analysis with the Shapiro-Wilk test showed, that the variable has a distribution close to normal. Therefore it is legitimate to use parametric tests for statistical data analysis. To verify whether the type of plywood differentiates the hardness, Student's t-test for independent samples was performed. Analysis showed no difference in hardness of control plywood and "mixed" one, for both artificially aged plywood and not treated with artificial aging process. Only artificial aging of "mixed" plywood resulted in statistically significant changes in hardness.

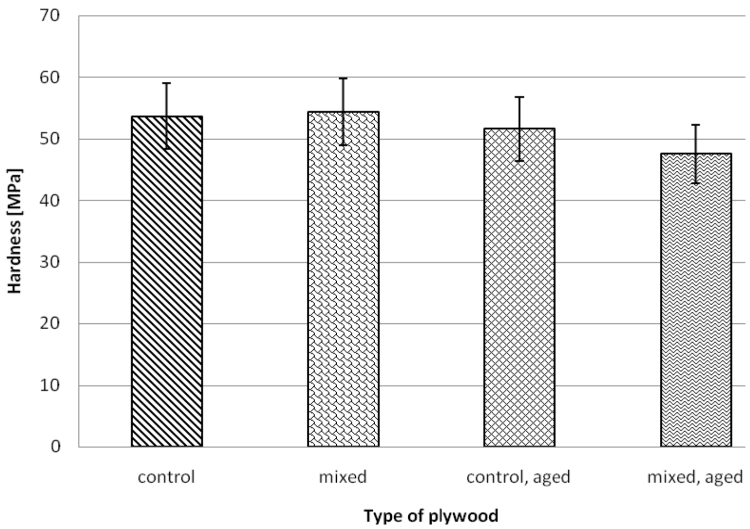

Fig. 3 The average Brinell hardness of all types of plywood

Swelling. Average values of water absorption in all directions for each type of plywood are presented in Figure 4. All plywood types show the largest linear swelling after 72 hours on the thickness of the sample. "Mixed" plywood is characterized by lower linear swelling on the thickness than non-modified plywood, for both artificially aged plywood and not treated with artificial aging process. It may be noted that the use of thermally modified veneers decreases linear swelling of plywood. The largest differences can be noticed in the swelling on the thickness of the plywood not treated with artificial aging process. However, artificial aging process also affects the swelling of plywood. Samples, which were subjected to artificial aging process show lower swelling on the thickness and larger in length and width, when compared to the plywood not treated with artificial aging process. Artificially aged plywood, both non-modified and "mixed", in spite of the lowest thickness swelling, is characterized with the worst visual condition after 72 hours of soaking. This plywood unglued, outer veneers were deformed and were characterized with higher swelling than the rest of plywood. Soaking has also affected on the colour of plywood. “Mixed” samples were characterized by darker coloration after 72 hours of soaking.

Analysis with the Shapiro-Wilk test showed that three variables deviate from a normal distribution. To verify whether the type of plywood varies the swelling, the Mann-Whitney U-test in three aspects was performed. Comparison of control plywood and "mixed" plywood not treated with artificial aging process showed no difference in swelling on the length and width of the samples and the significant differences in the thickness swelling. In case of artificially aged plywood, the analysis of differences for the average values showed significant differences in swelling on the length and width of the samples, while no difference in the thickness swelling. Analysis of the impact of artificial aging process on swelling of plywood showed significant differences in swelling on the length, width and thickness of the of control plywood samples and no differences in swelling on the length and width of the “mixed” plywood samples, but substantial differences in swelling on the thickness.

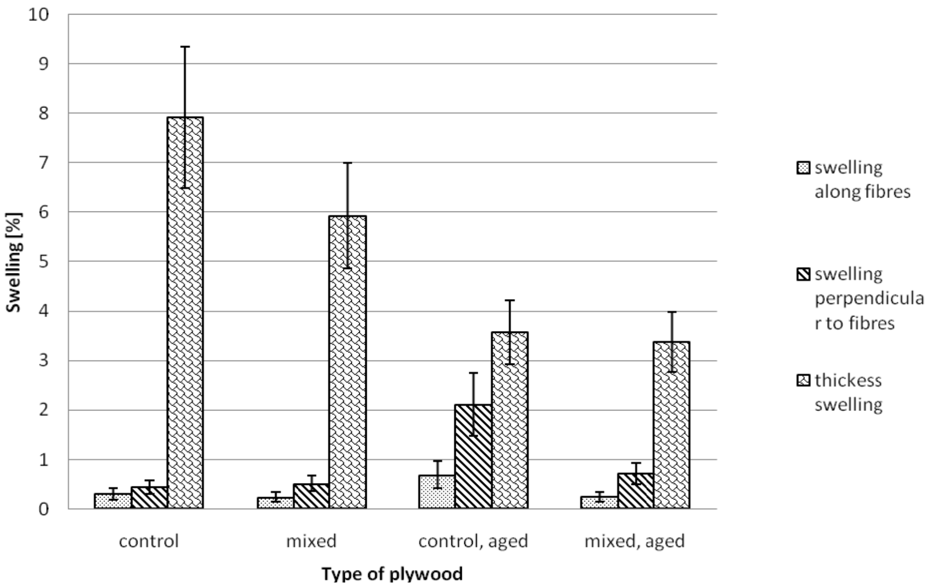

Fig. 4 Swelling of all types of plywood, depending on the direction.

Water absorption. Water absorption curves for the tested types of plywood are shown in Figure 5. Samples of all types of plywood showed the highest water absorption in the first 3 hours of soaking. Use of thermally modified veneers to manufacture of plywood reduces their absorption. In case of plywood not treated with artificial aging process, differences in water absorption between non-modified plywood and "mixed" plywood amounted to 6.6%, while in the artificially aged plywood reached 3.2%. Artificial aging increased the water absorption for both control plywood and "mixed" plywood. In comparison to the plywood not treated with artificial aging process, those that were artificially aged absorbed water rapidly in the initial stage of soaking, reaching similar degree of water absorption after 72 hours.

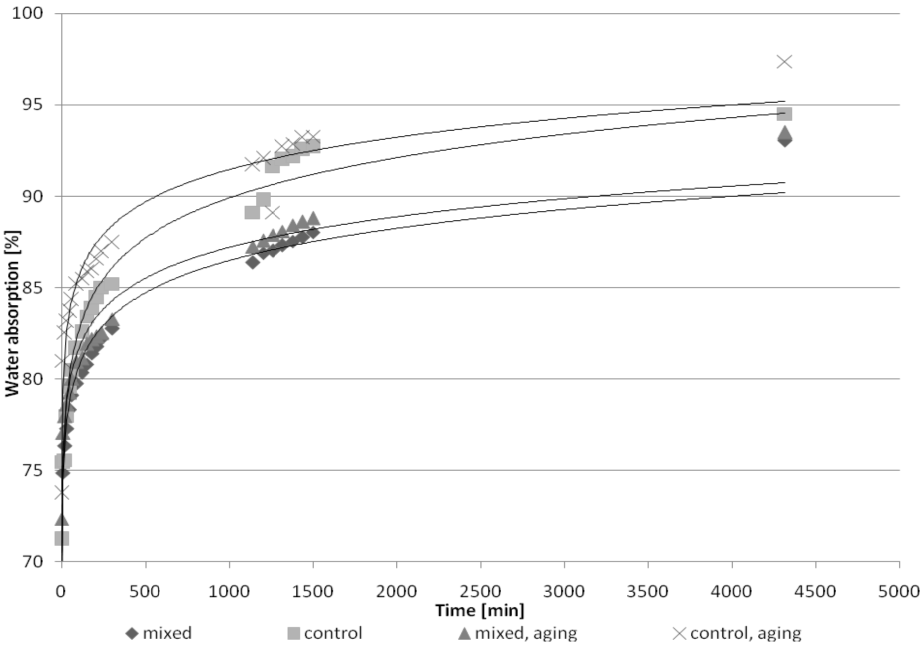

Fig. 5 Curves of water absorption of all types of plywood

CONCLUSIONS

1. The addition of thermally modified veneers into the structure of plywood causes decrease in its static bending modulus of elasticity along and across the fibres of plywood in comparison to the control plywood.
2. Artificially aged "mixed" plywood, as well as plywood not treated with artificial aging process, has higher static bending strength along the fibres in relation to the control plywood, but lower bending strength across the fibres.
3. Production of plywood from thermally modified and non-modified veneers reduces its swelling in all directions.
4. The use of thermally modified veneers for the manufacture of plywood reduces its water absorption.
5. Process of artificial aging of plywood reduces the value of static bending modulus of elasticity, static bending strength and hardness and increases water absorption of plywood. Artificially aged plywood is characterized with lower swelling on the thickness, and higher in length and width, when compared to the plywood not treated with artificial aging process.

REFERENCES

1. GRZEŚKIEWICZ M., BORYSIUK P., JASKÓŁOWSKI W. 2009: Physical and mechanical properties and burning behaviour of beech plywood made of thermally modified veneers. Proceedings of the International Panel Products Symposium, p. 81-88.
2. GRZEŚKIEWICZ M., LASKOWSKA K. 2010: Moulded plywood elements for furniture made of thermally modified beech veneers. Annals of Warsaw University of Life Sciences – SGGW, *Forestry and Wood Technology*, no. 70, p. 139-143.

3. JANKOWSKA A. 2010: Comparative analysis of wood ageing methods. Annals of Warsaw University of Life Sciences – SGGW, *Forestry and Wood Technology*, No. 71, p. 257-279.

Streszczenie: *Badanie właściwości fizyko–mechanicznych sklejki z łuszczki niemodyfikowanej i modyfikowanej termicznie*. Forniry bukowe zostały poddane modyfikacji termicznej w warunkach laboratoryjnych, w atmosferze przegrzanej pary wodnej, w temperaturze 170^{o}C w czasie 3 godzin. Z fornirów niemodyfikowanych i modyfikowanych termicznie, ułożonych naprzemiennie, wykonano 9-warstwowe sklejki, tak, że forniry niemodyfikowane stanowiły zewnętrzne warstwy sklejek. Sklejki zostały wykonane w warunkach przemysłowych z zastosowaniem żywicy UF. Część sklejek została poddana procesowi sztucznego starzenia w warunkach laboratoryjnych. Określono moduł sprężystości, wytrzymałość na zginanie statyczne w kierunku wzdłuż i w poprzek włókien, twardość oraz spęcznienie sklejek. Ponadto wyznaczono krzywe nasiąkliwości i spęcznienie dla wszystkich rodzajów sklejek. Badania przeprowadzono zgodnie z normami PN-EN. Dodatek fornirów modyfikowanych termicznie do sklejki obniża moduł sprężystości tego materiału ale równocześnie redukuje spęcznienie i nasiąkliwość sklejki.

Author’s addresses

Marek Grześkiewicz,
Faculty of Wood Technology,
Department of Construction and Technology of Final Wood Products,
166 Nowoursynowska str.
02-776 Warsaw, Poland
e-mail: marek_grzeskiewicz@sggw.pl