Annals of Warsaw University of Life Sciences - SGGW
Forestry and Wood Technology № 92, 2015: 263-267
(Ann. WULS - SGGW, For. and Wood Technol. 92, 2015)

Retention of polymer in lime wood impregnated with Paraloid B-72 solution in butyl acetate

PIOTR MAŃKOWSKI, PAWEŁ KOZAKIEWICZ, SŁAWOMIR KRZOSEK

Department of Wood Science and Wood Preservation, Faculty of Wood Technology, Warsaw University of Life Sciences - SGGW, 159 Nowoursynowska St., 02-776 Warsaw

Abstract: Various types of polymers introduced into antique wood structure are used in the process of its consolidation. The effectiveness of the impregnation procedure is determined by - among others - the retention of protective substance. In the present work the retention of the polymer in lime wood once and twice saturated Paraloid B-72 solution in butyl acetate was examined. While maintaining identical conditions of impregnation, during the first impregnation cycle obtained retention is twice bigger than in the second cycle. The value of retention depends on the initial density of lime wood. With the increase of the density (and decrease of porosity) the absorption of the polymer decreases linearly.

Keywords: lime wood, density of wood, porosity of wood, Paraloid B-72, polymer retention

INTRODUCTION

The process of wood structural reinforcement is often used in wood preservation. Strengthening consist of introducing the polymer solutions to timber degraded by biological factors. After evaporation of the solvent polymers reinforce its structure. The most common treatments used to wood strengthening are acrylic polymers (commonly used Paraloid B-72), and - less frequently used - vinyl polymers (Winacet R). As the solvent there are used these liquids which: dissolve the polymer, penetrate into the wood and do not cause color reactions with components of wood (and optionally do not damage the paint). The key parameter is the degree of swelling of the wood as a result of interaction with the solvent. In the choice of solvent also its toxicity, explosiveness and flammability should be taken into consideration [Aurerson 2000]. For example, according to a study of Paciorek [1993] the greatest degree of wood saturation was obtained using Paraloid dissolved in methanol, however, due to the strong swelling caused by the methanol, it could not be applied in practice of conservation.

Therefore, the most commonly used solvent is toluene. The solution of Paraloid B-72 with a low concentration of the polymer penetrates the wood the best, but effective strengthening requires repeated impregnation and evaporation of the solvent. Too high levels of saturation cause significant supersaturations of subsurface layers and weak penetration of the solvent into the deeper layers of wood [Schniewind in 1990, Wang and Schniewind 1985]. Schniewind and Eastman [1994] in their research determined polymer content of vessels of damaged wood impregnated with 20% Paraloid B-72 solution in toluene and it was found that at a depth of more than 7 mm from the surface in approx. 10% of wood vessels polymer is present. Better supersaturation of wood was obtained by using Paraloid acetone solution. According to the cited authors, resins migrate to the surface of the wood in the process of solvent evaporation.

According to Wiłkojć [2012] the level of conservator resin saturation in wood decreases as the distance from the object surface increases. Morover, Wójtowicz [1983] stated that the saturability of wood depends largely on the type of wood (in the same conditions of saturation he gained significantly different values of impregnation absorbency). Another factor, which has influence on saturability of wood is degree of decay of wood by fungi [Jankowska, Krajewski, Tarasiuk 2010]. Samples of natural wood, showed lower retention of Paraloid B-72 than the

samples decay by the fungus *Coniophora puteana* (Schumach.) P. Karst. [Mańkowski and Andres 2015]. Also impregnation time have an impact on retention of polymers [Tuduce et al, 2011]. Currently, there are attempts to determine the retention of the polymer in the wood using methods of tomography and radiography [Kucerowa, Ohlídalová, Lehmann 2009, Kucerowa 2012].

The aim of the study is to determine the average retention of polymer in lime wood once and twice saturated with Paraloid B-72 solution in butyl acetate and to reference obtained results to wood density.

MATERIAL AND METHODS

To the study there were prepared a total of 60 samples of wood, which dimensions are 20x20x30 mm, cut according to main anatomical sections from small-leaved lime (*Tilia cordata* Mill.). These samples were divided into two equal groups: saturated once (WI) and impregnated twice (WII). All samples (WI, WII) before saturation process were adjusted to a constant mass at. 60ºC and their density was determined in accordance with ISO 13061-2:2014. Assuming the density of the wood substance of 1.5 g/cm^3 (density of cell-wall) also the porosity of the wood in completely dry state can be determined using following relationship:

$$C = \frac{\varsigma_s - \varsigma_o}{\varsigma_s} \cdot 100\%$$

where: C – porosity of wood [%],
ς_s – density of wood substance (ς_s=1,5 g/cm^3),
ς_o – density of dry wood [g/cm^3].

Wood samples WI and WII were impregnated with 10% Paraloid B-72 solution in butyl acetate for 30 minutes in vacuum (760 mmHg underpressure). Then saturated samples were left flooded in impregnating solution for a week. After that they were removed from solution and evaporated in a fume hood. For a group of samples WII these steps were performed twice - the conditions of impregnation and solvent evaporation during both impregnation processes were identical.

After evaporation of the solvent from the impregnated samples (WI and WII) they were re-adjusted to constant weight at 60°C and their density was determined. The retention of the polymer was calculated from the formula:

$$R = \frac{m_n - m_o}{V_o}$$

where: R- retention of polymer [g/cm^3],
m_n – mass of wood after polymer saturation [g],
m_o – mass of dry wood [g],
V_o – volume of dry wood [cm^3].

RESULTS AND DISCUSSION

Average density of investigated lime wood in absolutely dry state before saturation was 519 kg/m^3 (with the extremes of 378 to 641 kg/m^3) in the group WI and 520 kg/m^3 in WII (with the extremes of 398 to 664 kg/m^3). The indicated ranges and averages should be regarded as similar in accordance with the data provided in the literature [e.g. Galewski and Korzeniowski 1958, Wagenführ 2007]. The density of the wood determines its porosity. This parameter specifies the volume of free spaces in wood, implicitly available to the polymer. The porosity of lime wood selected to the test was high and varied in the range approx. 55 to 75% (mean value 65%).

Investigated lime wood (both sample groups) was characterized by a relatively high coefficient of variation of density and porosity of approx. 13%. It was intentional, because it allows to capture the impact of the density of the wood on the size of retention.

As a result of single saturation of lime wood with Paraloid B-72 solution, the value of obtained polymer retention was approx. 10%. Retention of the polymer shows the dependence on the density of the wood samples. With the increase of wood density the retention slightly decreases, as it was confirmed by other studies [Mańkowski and Andres 2015]. Repeated impregnation results in approx. 5% increase of retention. It also shows the dependence on density. The relationship between wood density and retention of polymer in both cases (single and double saturation) are linear (Figure 1).

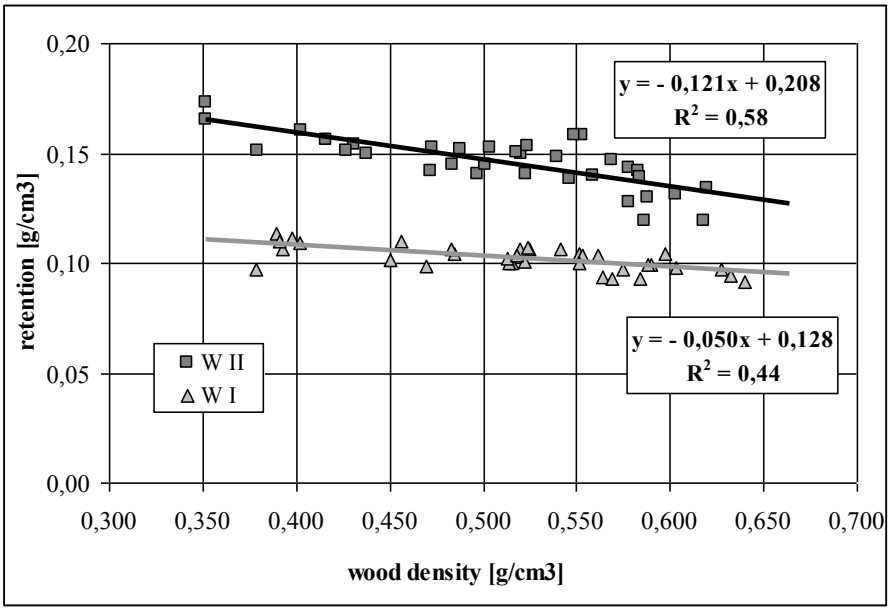

Figure 1. The relationship between the density of dry small-leaved lime wood and retention of polymer (Paraloid B-72)

With the same increase of the original density of wood, decrease in retention in the second impregnation of Paraloid B-72 is slightly larger than in the first impregnation. The determination coefficient of the line illustrating the relationship after the second impregnation is 0.58, and in the single impregnation case - 0.44. The results of retention changes indicate that the polymer is deposited mainly in the lumen of cell wood, and the most significant parameter determining the size of retention was wood porosity, what confirms the results of previous studies of lime wood impregnation with Paraloid B-72 solution in toluene [Kozakiewicz et. al. 2011].

CONCLUSIONS

From the study of retention of Paraloid B-72 in lime wood (*Tilia cordata* Mill.) the following conclusions were enunciated:

1. The density of investigated dry lime wood averaged approx. 0.52 g/cm^3 and varied over a wide range typical for this species. The average porosity of the wood was approx. 65% varying in the range of 55 to 75%.

2. After a single saturation of lime wood according to the methodology described in this paper the average retention of Paraloid B-72 is approx. 0.10 g / cm3 and after double saturation - 0.15 g/cm^3.
3. The original density of lime wood significantly affect retention of polymer during both single and at double-impregnation processes. With the increase in wood density and thereby decrease of wood porosity, retention decreases in a linear manner.

REFERENCES

1. AUGERSON Ch., 2000: The use of less toxic solvents in the treatment of ca royal french slench, ca 1720 (http://cool.conservation-us.org/coolaic/sg/wag/2000/WAG_00_augerson.pdf)
2. GALEWSKI W., KORZENIOWSKI A., 1958: Atlas najważniejszych gatunków drewna. Państwowe Wydawnictwo Rolnicze i Leśne.
3. ISO 13061-2:2014 Physical and mechanical properties of wood – Test methods for small clear wood specimens – Part 2: Determination of density for physical and mechanical tests
4. JANKOWSKA A., KRAJEWSKI K.J., TARASIUK S., 2010: The effect of polymethyl methacrylate impregnation on mechanical properties of pine wood degraded by fungi, Drewno. Pr. Nauk. Donies. Komunik. 2010, vol. 53, nr 183
5. KOZAKIEWICZ P., MAŃKOWSKI P., WIŁKOJĆ E., 2011: Evaluation of Paraloid B-72 lime wood reinforcement efficiency. Annals of Warsaw University of Life Sciences – SGGW, Forestry and Wood Technology No 74, s. 216-220
6. KUCEROWA I., OHLÍDALOVÁ M., LEHMANN E., 2009: Monitoring of acrylic solution penetration into wood with Raman spectroscopy and neutron radiography (http://www.woodculther.com/wp-content/uploads/2009/09/3-kucerova-comp.pdf)
7. KUČEROVÁ I. 2012, Methods to measure the penetration of consolidant solutions into `dry` wood, Journal of Cultural Heritage, vol. 13 S, pp. 191-195.
8. MAŃKOWSKI P., ANDRES B., 2015: Compressive strength of wood *Pinus sylvestris* decayed by *Coniophora puteana* fungi and reinforced with Paraloid B-72, Wood Research (in press).
9. PACIOREK M., 1993: Badania wybranych tworzyw termoplastycznych stosowanych do impregnacji drewna Studia i materiały WKiRDS ASP Kraków, Wyd Literackie
10. SCHNIEWIND A.P., 1990: Solvent and moisture effect in deteriorated wood consolidated with soluble resin, Holz and Roh- und Werkstoff 48, 1990, pp.11-14
11. SCHNIEWIND A.P., EASTMAN P.Y., 1994: Consolidant distribution in deteriorated wood treated with soluble resins, JAIC v.33.nr 3, 1994, pp. 247-255
12. TUDUCE TRAISTARU A.A., TIMAR M.C., CAMPEAN M., 2011: Studies upon penetration of Paraloid B72 into poplar wood by cold immersion treatments Bulletin of the Transilvania University of Brasov Series II: Forestry Wood Industry Agricultural Food Engineering Vol. 4 (53) No. 1 – 2011, Brasow 2011
13. WAGENFÜHR R., 2007: Holzatlas.6., neu bearbeitete und erweitere Auflage. Mit zahlreichen Abbildungen. Fachbuchverlag Leipzig im Carl Hanser Verlag
14. WANG Y., SCHNIEWIND A.P., 1985: Consolidation of deteriorated wood with soluble resins JAIC v. 24, Nr 2, 1985, pp. 77-91
15. WIŁKOJĆ E., 2012: Christ Blessing The Children by Lucas Cranach the Elder in the Collection of the Wawel Royal Castle, study and conservation, Publishing by Wawel Royal Castle, Cracow
16. WÓJTOWICZ A., 1983: Niektóre aspekty modyfikowania drewna za pomocą związków winylowych, Wyd. SGGW-AR

Streszczenie: *Retencja polimeru w drewnie lipowym nasyconym roztworem paraloidu B-72 w octanie butylu.* Do konsolidacji drewna zabytkowego stosowane są między innymi różnego rodzaju polimery wprowadzane do jego struktury. O skuteczności zabiegu impregnacji decyduje miedzy innymi retencja substancji zabezpieczającej. W ramach niniejszej pracy zbadano retencję polimeru w drewnie lipowym (*Tilia cordata* Mill.) jednokrotnie i dwukrotnie nasyconym roztworem paraloidu B-72 w octanie butylu. Przy zachowaniu identycznych warunków impregnacji w pierwszym cyklu nasycania retencja była dwukrotnie większa (średnio ok. 10 g/m^3) od uzyskanej w drugim cyklu nasycania (wzrost ok. 5 g/m^3). Na wielkość retencji wpływa naturalna gęstość drewna lipowego. Wraz ze wzrostem gęstości drewna lipy w sposób liniowy zmniejsza się wchłanianie polimeru. Wchłanianie to jest ściśle uzależnione od objętości wolnych przestrzeni w drewnie charakteryzowanych poprzez jego porowatość w stanie absolutnie suchym.

Corresponding authors:

Piotr Mańkowski
Department of Wood Sciences and Wood Protection
Faculty of Wood Technology
Warsaw University of Life Sciences – SGGW
159 Nowoursynowska St.
02-776 Warsaw, Poland
email: piotr_mankowski@sggw.pl
http://piotr_mankwski.users.sggw.pl
phone: +48 22 59 386 38

Paweł Kozakiewicz
Department of Wood Sciences and Wood Protection
Faculty of Wood Technology
Warsaw University of Life Sciences – SGGW
159 Nowoursynowska St.
02-776 Warsaw, Poland
email: pawel_kozkiewicz@sggw.pl
http://pawel_kozakiewicz.users.sggw.pl
phone: +48 22 59 38 647
fax: +48 22 59 386 59

Sławomir Krzosek
Department of Wood Sciences and Wood Protection
Faculty of Wood Technology
Warsaw University of Life Sciences – SGGW
159 Nowoursynowska St.
02-776 Warsaw, Poland
email: slawomir_krzosek@sggw.pl
phone: +48 22 59 386 33