

## **Influence of wooden floor surface finish on its hardness and resistance to abrasion**

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**Abstract:** *Influence of wooden floor surface finish on its hardness and resistance to abrasion.* Traditional methods of wood impregnation consisted in soaking it with substances of natural origin: vegetable oils, beet sugar, cane sugar, paraffin, colophony, waxes, potassium alum, etc. The surface of antique wooden parquets was soaked with wax or with oils. The research was aimed at specifying the properties of different finish coatings used as traditional means of wooden floor surface finishing, by analysing the changes in hardness and resistance to abrasion of samples without finish coating and samples covered with wax, varnish (natural linen oil), as well as contemporary synthetic parquet oil combined with wax oil. Research was carried out on antique and contemporary wood samples. The tests of wood hardness were done in accordance with the Brinell method, in line with the PN-EN 1534:2011 standard. The abrasion resistance was measured with the Taber method on the basis of mass loss, in accordance with PN-EN ISO 5470-1:2001 standard. We assumed that the following factors have influence on hardness and resistance to abrasion: wood species, origin (manor house and room) and layout of parquet elements within the room, which determined the intensity of usage of a given element and the climate conditions around the wood (traffic, internal or external room corner).

*Keywords:* antique wooden parquet, surface finish, hardness, resistance to abrasion

### INTRODUCTION

Traditional methods of wood impregnation consisted in soaking it with substances of natural origin: vegetable oils, beet sugar, cane sugar, paraffin, colophony, waxes, potassium alum, etc. [Kurpik, Ważny 2004]. The surface of antique wooden parquets was soaked with wax or with oils. Wax was applied at the temperature of 180°C with the help of scrapers or brushes. The excess of congealed wax was removed with a scraper, leaving only the part that was absorbed by the wood. The action was repeated many times, carefully as not to cause smudges on the surface as a result of uneven spreading of wax. The collected excess of wax couldn't be used again, because it contained dyes and tannins from the wood. After soaking, the parquets were polished until gloss was obtained [Kuczyńska-Cichocka 1999]. A parquet covered with wax required regular maintenance consisting of periodic removal of dirt, polishing to obtain gloss, as well as replenishing the wax layer approximately once per year, depending on the intensity of usage. Varnishing (repeated soaking with hot linseed varnish until total saturation of the wood surface) was not used for intarsia floors, because it darkened the colours of wood significantly and resulted in the lack of gloss. However, it was used to finish the surface of single colour parquets. Varnishing created a quite durable effect – no scratches or stains caused by contact with water were visible on the parquet surface and it was quite easy to refresh by applying another layer of oil. These substances are not film-forming, although their depth of penetration is small. Nowadays, varnish has been replaced with more or less synthetic parquet oils applied cold, whose surface is additionally covered with wax oil [Olejowski- naturalna pielęgnacja podłóg (*Wax Oils – Natural Floor Maintenance*, 2009) New products in the offer of Blanchon Polska 2009]. However, wax oil is a film-forming substance and is often affected by scratching and abrasion [Bortnowski 2008].

The parquet finish has a major influence on its durability. Finishing the parquet surface with wax or oil improves its resistance to abrasion. The literature mentions significant changes in the abrasion resistance of beech, oak and pine wood. After saturating with wax, the

abrasion resistance of beech wood is even better than the abrasion resistance of maple wood saturated with wax [Korzeniowski 1956].

#### AIM OF RESEARCH

The research was aimed at specifying the properties of different finish coatings used as traditional means of wooden floor surface finishing, by analysing the changes in hardness and resistance to abrasion of samples without finish coating and samples covered with wax, varnish (natural linen oil), as well as contemporary synthetic parquet oil combined with wax oil [Róžańska i in. 2012, Róžańska, Beer 2012].

#### INVESTIGATED MATERIAL

Research was carried out on antique wood samples from two parquets whose relocation was recommended: oak parquet from Room no. 4 of the Tarnowiec Manor House and elm parquet from Room no. 5 of the Tarnowiec Manor House, as well as contemporary European oak (*Quercus sp*), elm (*Ulmus sp*), ash (*Fraxinus excelsior L.*) and pine wood (*Pinus sylvestris L.*).

The dimensions of test samples were about 100 x 100 mm. The thickness of individual samples ranged between 10-25mm and decreased over time.

Antique wood samples were collected from the parquet in three sampling points within each room (sampling point 1 – external corner of the room; sampling point 2 – traffic paths; sampling point 3 – internal corner of the room).

The samples of wood from antique parquets were compared with control samples of contemporary wood prepared in an analogous manner and having similar parameters concerning the growth rings, the type of section and the density of wood. They were obtained from different construction material storage sites located in South-Eastern Poland.

Batches of antique wood samples and contemporary wood samples tested without surface finish were divided randomly into several groups. Contemporary wood samples were covered with wax and varnish. Antique wood samples were covered with wax, varnish and contemporary parquet oil combined with wax oil. The number of samples for each kind of finish was about 10 for each sample batch, but not less than 6 samples. Sample characteristics are presented in Table 1.

Before applying the coatings, the surface of samples was prepared by polishing with sand paper with grit of ca. 50 – 100 - 150. This task was performed manually, because of the changes to the properties of wood surface that occur as a result of high temperature that is created during mechanical processing [Sandak, Sandak 2009].

We used natural bee wax from an apiary provided in combs, varnish produced by the Drewnochron company (98% of linen oil and 2% of drying agents) prepared in accordance with a traditional formula [Kinney 1971, Frid 1981] and contemporary synthetic parquet oil Bona Carl's 90, covered with Fiddes *Hard Wax Oil* (commonly used due to its low price).

Varnish was applied hot, with the help of a brush, until the surface was entirely saturated. Wax was applied by pressing wax bars (made of melted bee wax) against the wood surface, and then it was rubbed into it by polishing with a piece of felt. Contemporary oil was applied twice with the help of a hard rubber applicator, until the surface was saturated, and afterwards the surface was polished first with a red pad and then with a soft cloth. After the oil had dried completely, after about two days, the surface was additionally covered with wax oil.

Before the tests, the samples were acclimatised (in conditions of: 20°C, 60% relative air humidity). The wood moisture equivalent differed depending on the wood species and its state of preservation and amounted to 9.4 on average. The highest moisture equivalent was observed in case of antique oak wood from Room no. 4 in Tarnowiec (10.2%).

## RESEARCH METHODOLOGY

**Hardness.** The tests of wood hardness were done in accordance with the Brinell method, in line with the PN-EN 1534:2011 standard. The measurements were made on the front side of the samples, 8 measurements on each sample.

**Abrasion resistance.** The abrasion resistance was measured with the Taber method on the basis of mass loss, in accordance with PN-EN ISO 5470-1:2001 standard. The number of revolutions was adjusted to the scope of investigations. In case of tests of different antique and contemporary wood species without finish coating, the results of mass loss were much more accurate after 1000 revolutions than after 100 revolutions recommended by the standard. However, the influence of the finishes on the abrasion resistance became less clear, as the finishes penetrated into the wood from 0.5 to 2 mm deep. For this reason, in case of wood covered with surface finishes, we decided to measure mass loss in accordance with the standard, after 100 revolutions. The results of mass loss after 1000 revolutions, obtained for wood without finish coating, were re-calculated to get standard values.

In case of hardness and resistance to abrasion, average test results have been presented for samples without surface finishes, and we observed the changes in hardness after the particular oak and elm samples were covered with wax and varnish.

**Statistic Interpretation of Test Results.** We assumed that the following factors have influence on wood properties: E – wood species (oak, ash, pine, elm), C – origin (manor house and room), D – layout of parquet elements within the room, which determined the intensity of usage of a given element and the climate conditions around the wood (traffic, internal or external room corner, “general” – without defining the sampling point). The layout of parquet elements in a room reflects the climate conditions that surrounded the wood. Therefore, we assumed that factor D (location) was hierarchically placed within the origin factor C (D was nested in C). We also analysed the influence of CDE factor, which identified the sample through its origin, species and climate around the wood. In case of samples finished with wax, varnish and contemporary oil, apart from the factors mentioned above, we have an additional factor AL – the kind of finish (oil, varnish, wax).

Data analysis was performed with the GLM procedure of the SAS statistic package.

The following statistic model was assumed for the experiment:  $Y=E+C+D(C)+\text{error}$ , where the E, C, D factors are constant. A more formal manner of recording this model is the following:

$$Y_{ijkl} = \mu + \alpha_i + \beta_j + \gamma(\beta)_{k(j)} + \varepsilon_{ijkl},$$

where:

$\mu$  - the base, on which the effects of the tested factors were calculated,

$\alpha_i$  - the i-effect for this wood species,

$\beta_j$  - the effect of the j room,

$\gamma(\beta)_{k(j)}$  - the effect of the j room,  $\gamma(\beta)_{k(j)}$ ,

$\varepsilon_{ijkl}$  - experiment error (errors of measurement + diversity of parquet panels),

$Y_{ijkl}$  - the tested property in the l-sample made of the i-wood species taken from the j-room and used with a k-intensity.

As to the errors  $\{\varepsilon_{ijkl}\}_{ijkl}$ , we assume that they are independent random variables with the same distribution  $N(0, \sigma^2)$  [normal distribution with the average 0 and variance  $\sigma^2$ ].

The values of the different indexes are shown in the Table no.2.

**Tab. 1** Characteristics of samples for the tests of finish coating properties

Origin	Date	Floor structure	Wood species	Sampling point	Finish + sample numbers
Tarnowiec Room no 4	ca.1930	sand + joists	Oak <i>Quercus sp.</i>	External room corner	varnish: (T4-1) 12, 17, 18, 36, 38, 39 wax: (T4-1) 13, 14, 15, 16, 19, 22 oil: (T4-1) 23-31, 34, 35
Tarnowiec Room no 4	ca.1930	sand + joists		Traffic paths	varnish: (T4-2) 4, 5, 13-16, 40 wax: (T4-2) 17, 20, 22, 23, 28, 30, 32 oil: (T4-2) 24-27, 33-39, 41, 42
Tarnowiec Room no 4	ca. 1930	sand + joists		Internal room corner	varnish: (T4-3) 18, 19, 22, 23, 30, 34, 35 wax: (T4-3) 12-14, 24, 25, 28, 29, 36-40
Tarnowiec Room no 5	ca. 1930	sand + joists	Elm <i>Ulmus minor</i> Mill.	External room corner	varnish: (T5-1) 14, 17-20, 27 wax: (T5-1) 23, 29-33 oil: (T5-1) 3, 5, 7, 8, 11-13, 22, 26
Tarnowiec Room no 5	ca. 1930	sand + joists		Traffic paths	varnish: (T5-2) 12, 14, 16, 18, 21, 24, 25, 29 wax: (T5-2) 1, 4, 8, 11, 27, 33 oil: (T5-2) 2, 3, 5, 15, 22, 26, 31, 32, 35, 39
Tarnowiec Room no 5	ca. 1930	sand + joists		Internal room corner	varnish: (T5-3) 5, 13-15, 23, 26, 39 wax: (T5-3) 3, 4, 12, 16, 18, 19, 24, 38 oil: (T5-3) 7-9, 11, 20, 22, 25, 27-29
Pine	contemporary	-	<i>Pinus sylvestris</i> L.	-	varnish: S-1, S-2, S-3; wax: S-4, S-5, S-6
Ash	contemporary	-	<i>Fraxinus excelsior</i> L.	-	wax: J-1, J-2, J-3; varnish: J-4, J-5, J-6
Oak	contemporary	-	<i>Quercus robur</i> L.	-	wax: D-1, D-2, D-3, D-4, D-5; varnish: D-6, D-7, D-8, D-9, D-10
Elm	contemporary	-	<i>Ulmus minor</i> Mill	-	wax: W-1, W-2, W-3, W-4, W-5; varnish: W-6, W-7, W-8, W-9, W-10

The interpretation of the SAS analysis concerns the influence of each factor on the tested property, with the significance level of 0.05. After discarding a given hypothesis, the Tukey-Kramer procedure was carried out to make detailed comparisons for the factor in question.

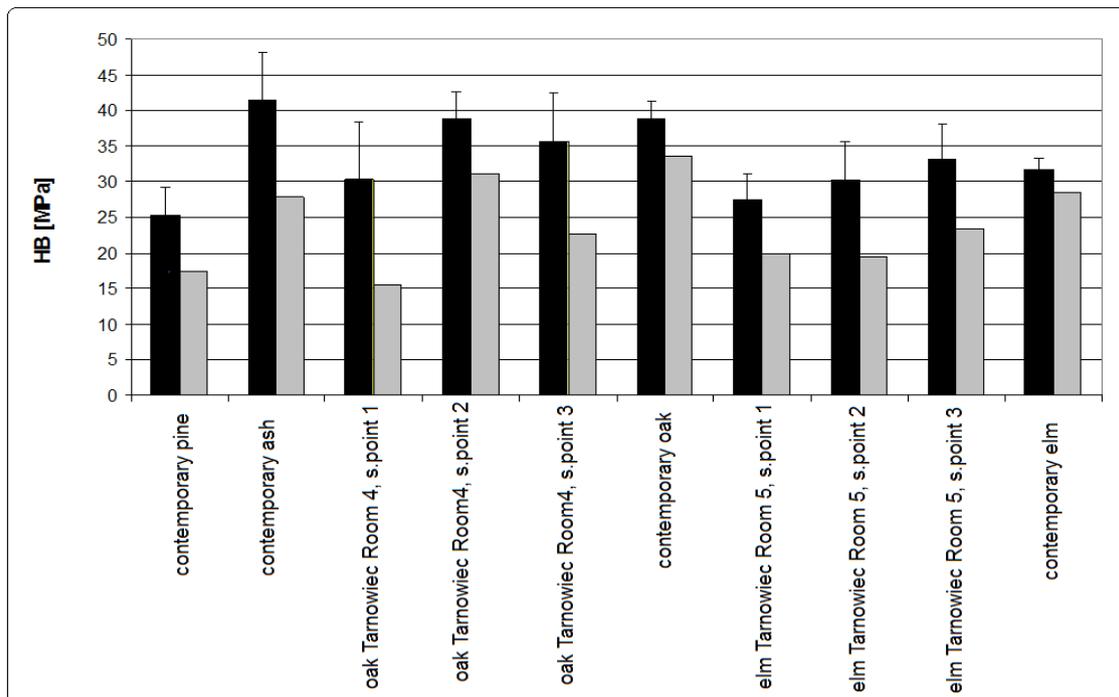
**Tab. 2** Values of the different indexes

D	E	C			
		1	4	5	7
Traffic paths	Oak	10	40	-	-
	Elm	-	-	40	-
General	Oak	-	-	-	10
	Ash	-	-	-	6
	Pine	-	-	-	6
	Elm	-	-	-	10
Internal	Oak	10	40	-	-
	Elm	-	-	39	-
External	Oak	10	43	-	-
	Elm	-	-	32	-

The interpretation of the SAS analysis concerns the influence of each factor on the tested property, with the significance level of 0.05. After discarding a given hypothesis, the Tukey-Kramer procedure was carried out to make detailed comparisons for the factor in question.

## TEST RESULTS

**Hardness.** The results of hardness tests in accordance to the Brinell method for samples covered with varnish, wax and contemporary oil combined with wax oil have been presented on the charts (Fig. 1-3).



**Fig. 1** Brinell hardness test results for samples covered with varnish together with the characteristic value

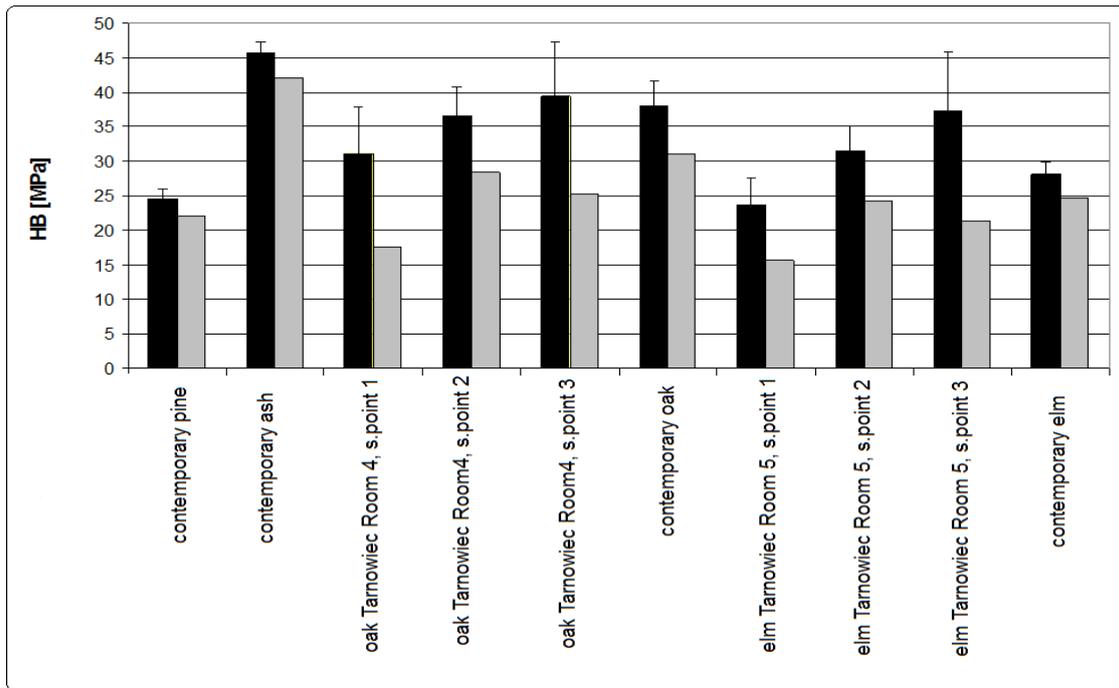


Fig. 2 Brinell hardness tests for samples covered with wax together with the characteristic value

In case of samples covered with varnish, the highest average hardness was observed for contemporary ash wood, and the lowest - for contemporary pine wood. Antique oak wood from Room no. 4, taken from the traffic path (sampling point no. 2) in the Tarnowiec Manor House has hardness that is similar to contemporary oak wood. Similarly, the hardness of antique elm wood from Room no. 5 taken from the traffic path and the internal corner of the room (sampling points no. 2 and 3) is comparable with the hardness of contemporary elm. The highest characteristic value of hardness was observed in contemporary oak wood, and the lowest – in antique oak wood from Room no. 4, from the external corner of the room – sampling point no. 1 - Tarnowiec Manor House.

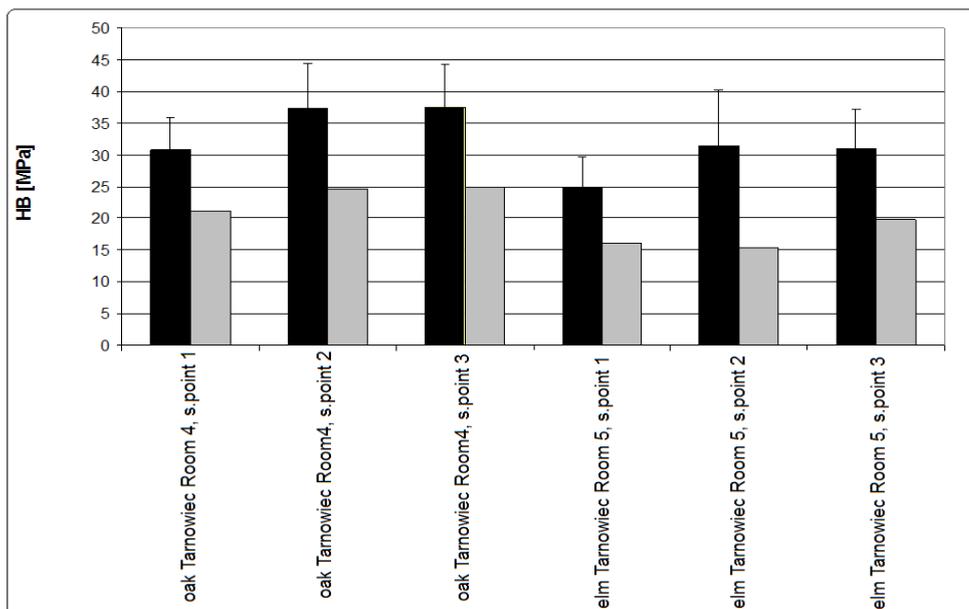
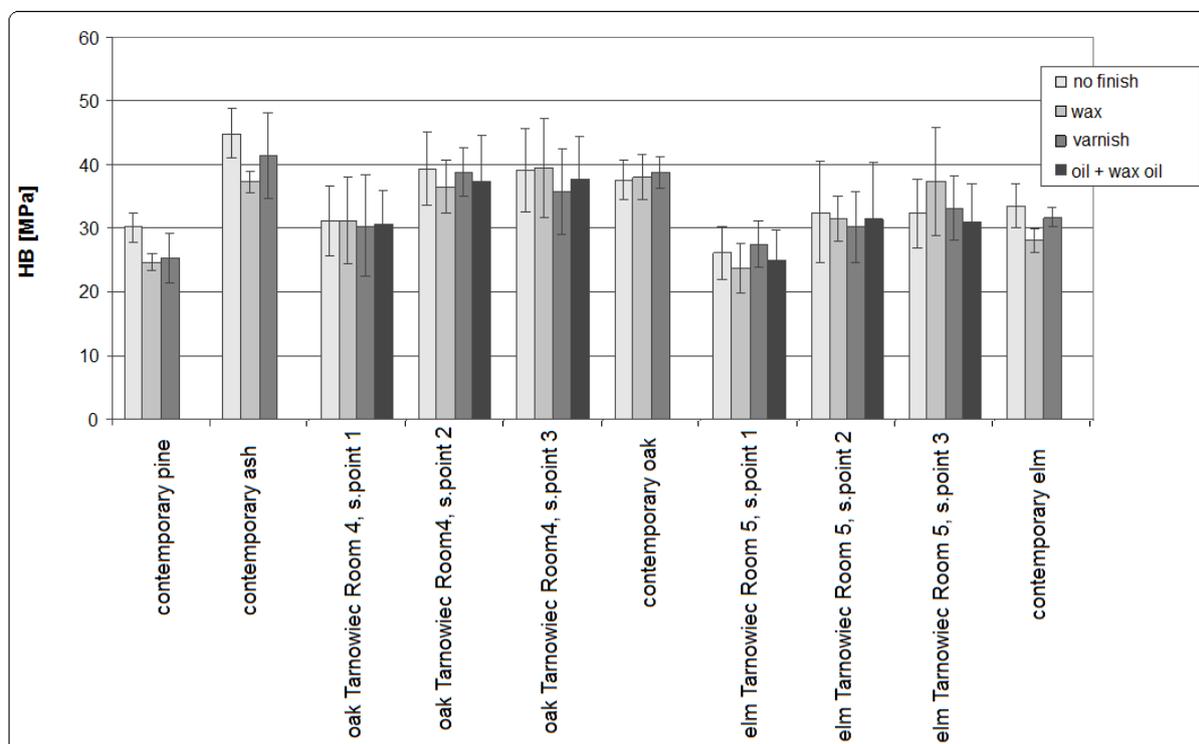


Fig. 3 Brinell hardness tests for samples covered with contemporary synthetic oil and wax oil together with the characteristic value

Ash wood covered with wax shows the highest average hardness and the highest characteristic hardness value. Although the wood from Room no. 4 taken from the internal corner of the room (sampling point no. 3) has higher average hardness than contemporary wood, yet its characteristic value lower than the characteristic hardness value of contemporary oak wood. The average hardness of antique elm wood from Room no. 5 taken from the traffic path and the internal corner of the room (sampling points no. 2 and 3) is higher than the average hardness of contemporary wood. However, the characteristic hardness value of contemporary elm wood is higher than the characteristic hardness value of antique wood.

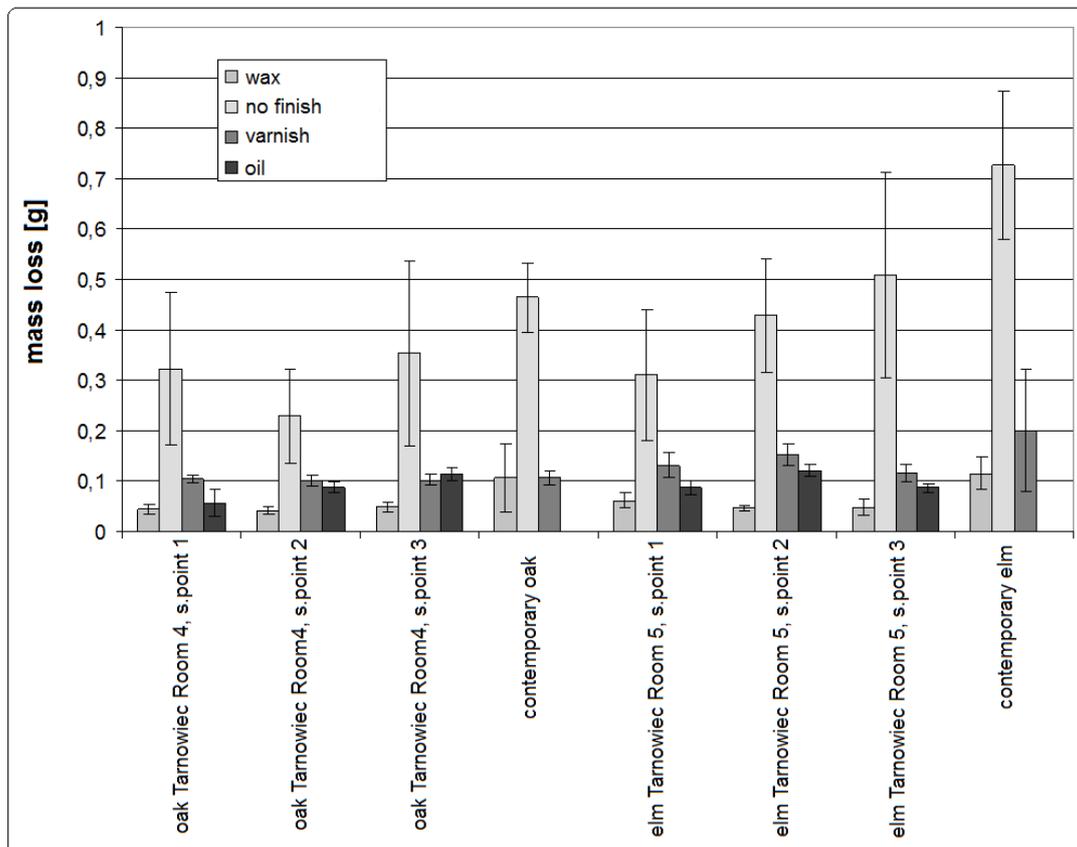
Among the samples of antique oak and elm covered with contemporary synthetic parquet oil and wax oil, the biggest characteristic hardness values were observed in case of samples taken from the internal corner of the room (sampling point no. 3). During the comparison of hardness test results for antique wood covered with varnish, wax and contemporary synthetic oil, one may see that the hardness is correlated with the sampling point, that is – with the microclimate around the wood.

The comparison of Brinell hardness test results of samples without finish and samples covered with varnish, wax and contemporary synthetic oil combined with wax oil, shows that the kind of surface finish does not have a major influence on the change in hardness in case of antique wood. The hardness results of antique and contemporary oak wood are comparable due to the standard deviation. A more significant decrease of Brinell hardness is observed in case of contemporary wood. For contemporary pine, ash and elm, the lowest hardness was observed in case of samples covered with wax (pine 24.6, ash 37.3, elm 28.1 MPa), higher values were observed in samples covered with varnish (pine 25.3, ash 41.4, elm 31.7 MPa) and the lowest in case of samples without finish (pine 30.1, ash 44.9, elm 33.4 MPa) (Fig.4).



**Fig. 4** Comparison of Brinell hardness values of samples without finish and samples covered with varnish, wax and contemporary synthetic oil combined with wax oil

**Abrasion resistance.** The abrasion resistance grows significantly after samples are covered with wax, varnish or synthetic oil, which can be observed both for antique wood and contemporary wood (Fig. 5). The biggest increase of average abrasion resistance occurred when the wood was covered with wax, and then synthetic oil and varnish correspondingly. It is worth mentioning that the standard deviation has much smaller values in case of samples covered with finish coatings.



**Fig. 5** Resistance to abrasion of samples without finish coating and samples covered with varnish, wax and contemporary synthetic oil combined with wax oil

The differences in average abrasion of oak samples covered with varnish compared with wood without finish amount to 68% for sampling point no. 1, 56% for sampling point no. 2 and 71% for sampling point no. 3 in Room no.4 D. The differences in abrasion of antique elm samples compared with wood without finish amount to 58% for sampling point no. 1, 65% for sampling point no. 2 and 77% for sampling point no. 3 in Room no.5 of the Tarnowiec Manor House. In case of contemporary oak and elm wood, its resistance to abrasion after covering with varnish improved by 77% and 72% in comparison with the abrasion value of wood without finish.

When wood was covered with contemporary synthetic oil, its average abrasion resistance improved by 83% for oak from sampling point no. 1, 62% for sampling point no. 2 and 68% for sampling point no. 3 in Room no. 4 of the Tarnowiec Manor House, in comparison with wood without finish. In case of antique elm samples from Room no. 5 of the Tarnowiec Manor House, its resistance to abrasion increased by 73% in samples from sampling points no. 1 and 2, and by 83% in case of sampling point no. 3, in comparison with wood without finish.

As we have mentioned before, the most significant drop in average abrasion was observed for wax finish. The mass loss of antique oak wood from Room no. 4 of the

Tarnowiec Manor House amounted to 87% for sampling points 1 and 3, and 82% for sampling point no. 2; while in case of antique elm from Room no. 5 of the Tarnowiec Manor House it amounted to 80% for sampling point no. 1, 89% for sampling point no. 2 and 90% for sampling point no. 3, in comparison with wood without finish. The mass loss of contemporary oak wood decreased by 77% and of elm wood by 84%, in comparison with the abrasion value of samples without finish.

After covering contemporary oak samples with wax or varnish, their average abrasion resistance improved in the same degree, while in case of elm, a higher percentage improvement of average abrasion was observed in case of wax finish. The dispersion of test results was bigger in case of contemporary oak covered with wax and contemporary elm covered with varnish, in comparison with antique wood covered with the same substances.

## CONCLUSIONS

1. In case of hardness differences between wood with and without finish, the wood species, its origin and the kind of finish are significant, while the climate factor is not.
2. Detailed comparisons as to the wood species prove that important differences in hardness are observed between oak and elm, ash and pine, and ash and elm.
3. Detailed comparisons related to the manner of finishing of contemporary and antique wood prove that the biggest difference in hardness between wood with and without finish occurs in case of wax, and the smallest, in case of varnish. The hardness differences of wood with and without finish are significant only between varnish and wax.
4. In case of differences in abrasion resistance measured as mass loss of wood with and without finish, all the factors proved to have a significant influence on the test results.
5. Detailed comparisons as to the wood species prove that after applying a finish coating of oil, varnish or wax, significant differences in mass loss in the abrasion process were observed between oak and pine, oak and elm, ash and pine, as well as ash and elm.
6. Detailed comparisons as to the kind of finish show that there are significant mass loss differences of wood with and without finish between varnish and wax. The biggest difference in mass loss between wood with and without finish occurred in case of samples covered with wax.

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**Streszczenie:** *Wpływ sposobu wykończenia powierzchni podłóg drewnianych na ich twardość i odporność na ścieranie.* Tradycyjnymi sposobami impregnacji drewna było jego nasączenie substancjami pochodzenia naturalnego: olejami roślinnymi, cukrem buraczanym, trzcinowym, parafiną, kalafonią, woskami, ałunem glinowo-potasowy itp. Powierzchnię zabytkowych posadzek drewnianych nasączało woskiem lub olejami. Badania miały na celu określenie właściwości różnych powłok wykończeniowych, tradycyjnie stosowanych jako wykończenie powierzchni podłóg drewnianych, poprzez analizę zmian twardości oraz odporności na ścieranie próbek niewykończonych oraz pokrytych woskiem, pokostem (naturalnym olejem lnianym), a także jednocześnie współczesnym syntetycznym olejem posadzkarskim i olejowoskiem. Badaniom poddano próbki drewna zabytkowego kilku dworów z południowo-wschodniej Polski oraz drewna współczesnego. Badania twardości drewna metodą Brinella przeprowadzono według normy PN-EN 1534:2011. Ścieralność metodą Tabera oznaczono na podstawie ubytku masy zgodnie z normą PN-EN ISO 5470-1:2001. Przeanalizowano wpływ gatunku drewna, pochodzenia (dwór oraz pomieszczenie) oraz położenia elementów posadzkowych w pomieszczeniu (przekładające się na intensywność użytkowania elementu oraz warunki klimatyczne, w jakich drewno przebywa) na twardość i odporność na ścieranie.

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