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Influence of wooden floor surface finish on its resistance to scratches

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Abstract: *Influence of wooden floor surface finish on its resistance to scratches.* The investigation of traditional wooden floor surface finish properties was also related to the changes in resistance to scratches of samples without finishing and samples covered with wax, with varnish and with contemporary parquet oil combined with wax oil. Research was carried out on antique and contemporary wood samples. The tests of resistance to scratches were performed on the basis of the PN-EN 438-2:2005 standard. The standard is used for finish coating tests and is not an accurate tool for testing wood without finish. In accordance to that standard, all the tested samples fall in the same group, because continuous scratches appeared already in case of the 1N force. However, the divergence between the degree of scratching was significant for different wood species, as well as for contemporary and antique wood. Therefore, the test results were calculated for the width of the scratches. We assumed that the following factors have influence on resistance to scratches: 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, resistance to scratches

AIM OF RESEARCH

The investigation of traditional wooden floor surface finish properties was also related to the changes in resistance to scratches of samples without finishing and samples covered with wax, with varnish and with contemporary parquet oil combined with wax oil [Różańska i in. 2012, Różańska, Beer 2012].

INVESTIGATED MATERIAL

The investigation was made on the same antique wood samples as in case of the tests of hardness and resistance to abrasion. Sample characteristics are presented in Table 1.

The dimensions of test samples were about 100 x 100 mm. The thickness of individual samples ranged between 10-25 mm 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, in accordance with the assumption that the parquets of antique manor houses were made of local materials.

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].

Tab. 1 Characteristics of samples for the investigation of changes in the resistance to scratches

Origin	Date	Floor structure	Wood species	Sampling point	Finish + sample numbers
Tarnowiec Room no 4	ca. 1930	sand + joists	Oak *Quercus sp.*	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 *Ulmus minor* 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	-	*Pinus sylvestris* L.	-	varnish: S-1. S-2, S-3; wax: S-4, S-5, S-6
Ash	contemporary	-	*Fraxinus excelsior* L.	-	wax: J-1, J-2, J-3; varnish: J-4, J-5, J-6
Oak	contemporary	-	*Quercus robur* 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	-	*Ulmus minor* Mill	-	wax: W-1, W-2, W-3, W-4, W-5; varnish: W-6, W-7, W-8, W-9, W-10

Similarly as in the previous case, 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

Resistance to Scratches. The tests of resistance to scratches were performed on the basis of the PN-EN 438-2:2005 standard.

The standard is used for finish coating tests and is not an accurate tool for testing wood without finish. In accordance to that standard, all the tested samples fall in the same group, because continuous scratches appeared already in case of the 1N force. Therefore, the test results were calculated for the width of the scratches.

The scratch width was measured with the accuracy of 0.01µm (with the help of a Nikon SMZ 1500 microscope connected to a digital camera, with the use of the NIS-Elements D 2.30 software) in 4 points with diagonal fibre layout for each of the forces. The choice of a diagonal fibre layout was related to the stability of scratch width (the width of scratches that were parallel to the fibres decreased over time, while in case of transverse fibre layout the scratches were not continuous, because the scratching device would "jump").

The scratch width method is less accurate than the 3D scanning method, because the test result depends on the place chosen for the measurement. However, in case of surfaces finished with varnish, the measurement of scratch depth for forces of 1-5 N with the help of 3D scanning proved to be ineffective, probably due to the surface gloss.

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).

Due to the fact that the tested material has a historical, patrimonial value, and due to the limitations related with this fact, the classification of the data gathered is not orthogonal and it is not possible to estimate the potential relations between the factors. For this reason, 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)+error, where the E, C, D factors are constant. A more formal manner of recording this model is the following:

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

where:

µ - the base, on which the effects of the tested factors were calculated,

α_i - the i-effect for this wood species,

β_j - the effect of the j room,

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

ε_{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 σ^2].

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

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

Resistance to Scratches. The scratch width tested on the different samples with and without finish substances shows that surface finishing with wax or varnish practically does not change the resistance to scratches. The scratch width in case of wood covered with wax, varnish and synthetic oil with wax oil is also comparable (Fig. 1-6).

When we take into account the standard deviation for 2 N, 3 N, 4 N and 5 N forces, the values of scratch width for oak samples from all the sampling points in Room no. 4 in the Tarnowiec Manor House are comparable (Fig. 1-3), similarly as in case of elm samples from sampling points 1 and 3 of the Room no. 5 in the Tarnowiec Manor House (Fig. 4 and 6). In case of the sampling point no. 2 in the Room no. 5 of the Tarnowiec Manor House, analogies can be seen only in case of the 5 N force (Fig. 5). The smallest average scratch width was observed in case of wood without a finish substance applied, although when we take into account the standard deviation, the difference is significant only in case of elm samples from the sampling point no. 2 in Room no. 5 in Tarnowiec.

The average scratch width of antique oak wood covered with wax, taken from the sampling point no. 1 in Room no. 4 in Tarnowiec (Fig. 1), in comparison with wood without a finishing substance, increased by 42% for 1 N force, 29% for 2 N force, 22% for 3 N force, 18% for 4 N force and 10% for 5 N force. In case of samples covered with varnish the differences were as follows: 40% for 1 N, 24% for 2 N, 18% for 3 N, 22% for 4 N and 12% for a 5 N force in comparison with the scratch width of wood without a finish coating. The application of synthetic oil on the surface increases the average scratch width by 22% for 1 N, 11% for 2 N and 3 N, and 6% in case of 4 N. The scratch width at 5 N force remained at a similar level.

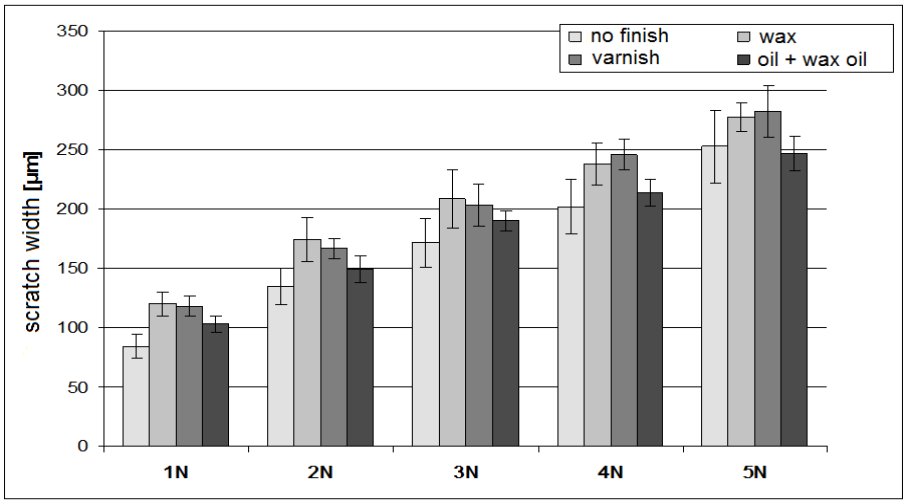

Fig. 1 Resistance to scratches of antique oak wood from Tarnowiec, Room no. 4, sampling point no. 1 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

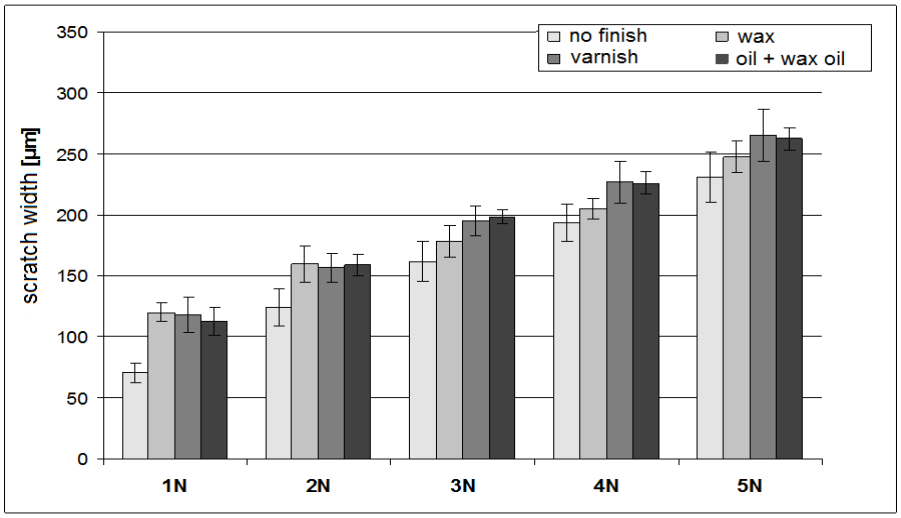

Fig. 2 Resistance to scratches of antique oak wood from Tarnowiec, Room no. 4, sampling point no. 2 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

In case of antique oak wood samples covered with wax taken from the sampling point no. 2 (Fig. 2) in Room no. 4 in the Tarnowiec Manor House, the scratch width increased by 70% for 1 N, 29% for 2 N, 10% for 3 N and 7% for 5 N, in comparison with the scratch width value of wood without finish. In case of wood covered with varnish, its scratch width increased by 67% for 1 N, 26% for 2 N, 21% for 3 N, 17% for 4 N and 15% for 5 N. In case of wood samples covered with contemporary oil and wax oil, the scratch width increased by 60% for 1 N, 28% for 2 N, 23% for 3 N, 17% for 4 N and 14% for 5 N, in comparison with the scratch width value of wood without finish.

Tab. 3 Percentage change of scratch width for antique oak wood from sampling point no. 3 in Room no. 4 of Tarnowiec Manor House in comparison with contemporary wood

	1N	2N	3N	4N	5N
Wax	83	38	25	19	12
Varnish	65	29	21	20	12
Oil+wax oil	69	25	22	18	12

The percentage change of scratch width for antique oak wood from the sampling point no.3 in Room no.4 of the Tarnowiec Manor House (Fig.3) has been presented in Table no.3.

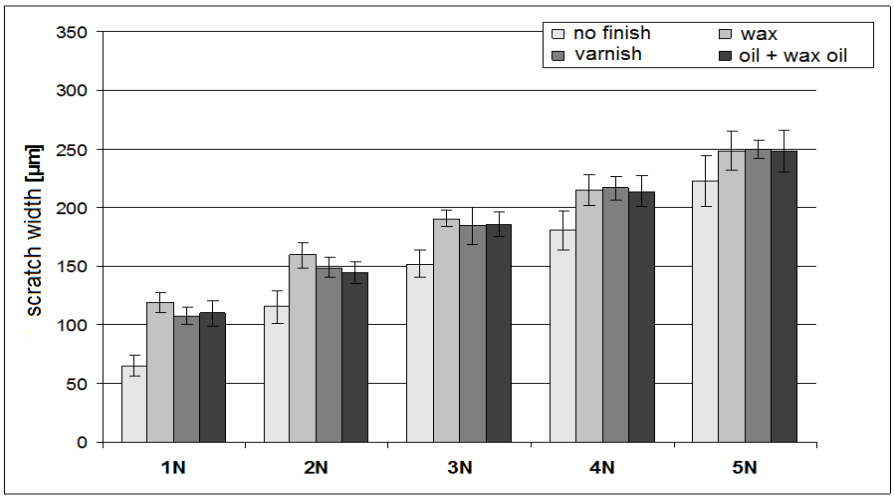

Fig. 3 Resistance to scratches of antique oak wood from Tarnowiec, Room no. 4, sampling point no. 3 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

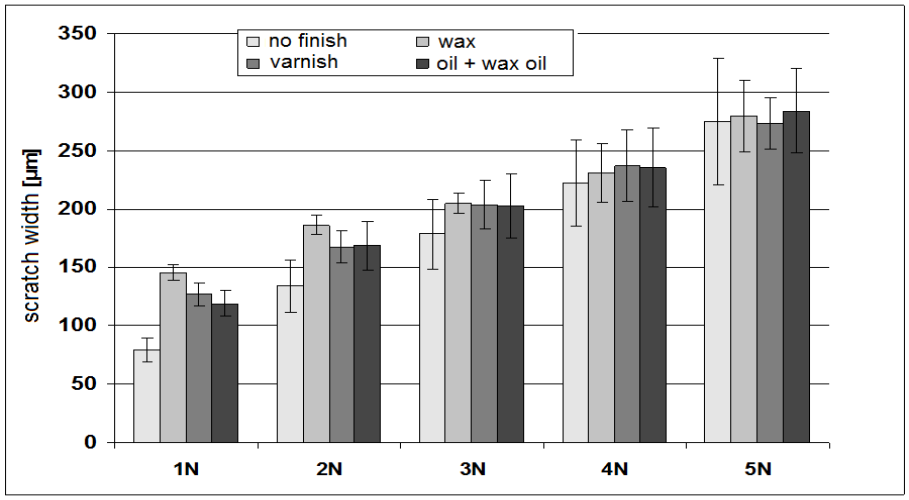

Fig. 4 Resistance to scratches of antique elm wood from Tarnowiec, Room no. 5, sampling point no. 1 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

In case of antique elm samples from the sampling point no.1 in Room no. 5 of the Tarnowiec Manor House (Fig.4) the scratch width in case of wood covered with wax increased by 83% for 1N, 39% for 2N, 15% for 3N, 4% for 4N and 2% for 5 N, in comparison with wood without finish. In case of wood covered with varnish, its scratch width increased by 60% for 1 N, 25% for 2 N, 14% for 3 N, 7% for 4 N and didn't change for 5 N. As to wood covered with contemporary synthetic oil, its scratch width increased by 50% for 1 N, 26% for 2 N, 14% for 3 N, 6% for 4 N and 3% for 5 N force.

The percentage change of scratch width for antique elm wood from the sampling point no.2 in Room no.5 of the Tarnowiec Manor House (Fig.5) has been presented in Table no.4.

Tab. 4 Percentage change of scratch width for antique elm wood from sampling point no. 2 in Room no. 5 of Tarnowiec Manor House

	1N	2N	3N	4N	5N
Wax	97	62	50	47	38
Varnish	84	52	39	30	29
Oil+wax oil	92	61	55	49	43

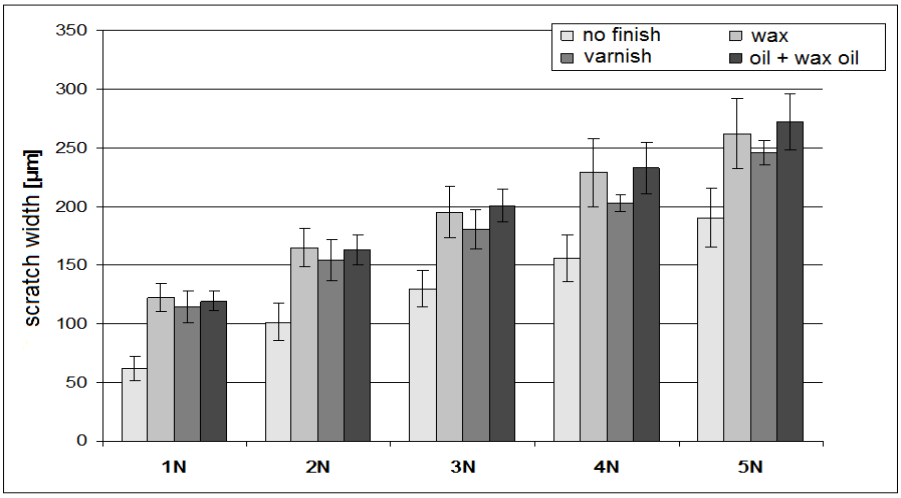

Fig. 5 Resistance to scratches of antique elm wood from Tarnowiec, Room no. 5, sampling point no. 2 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

The percentage change of scratch width for antique elm wood from the sampling point no.3 in Room no.5 of the Tarnowiec Manor House (Fig.6) has been presented in Table no.5.

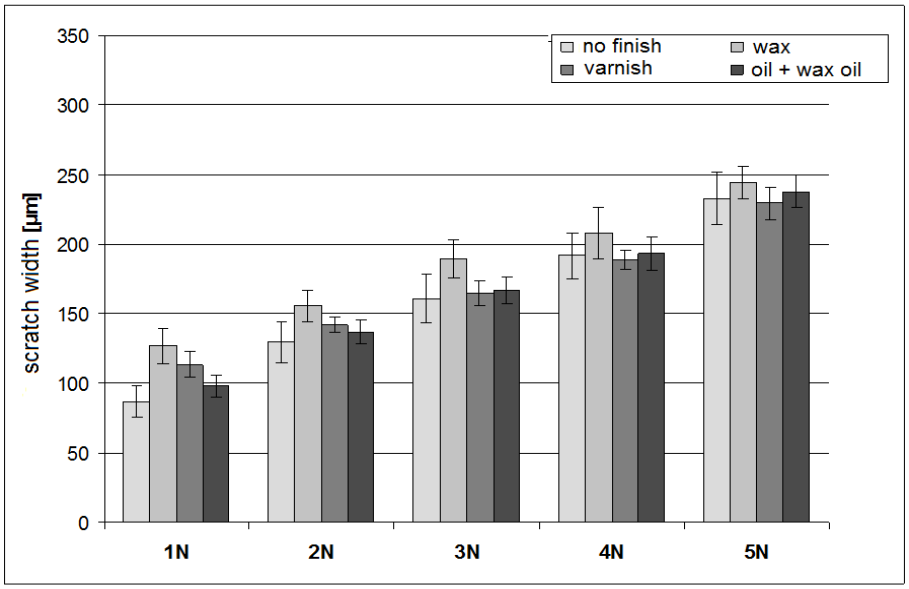

Fig. 6 Resistance to scratches of antique elm wood from Tarnowiec, Room no. 5, sampling point no. 3 (average scratch width for the forces: 1N, 2N, 3N, 4N and 5N)

Tab. 5 Percentage change of scratch width for antique elm wood from sampling point no. 3 in Room no. 5 of Tarnowiec Manor House

	1N	2N	3N	4N	5N
Wax	46	20	18	9	5
Varnish	31	10	2	-1	-2
Oil+wax oil	13	5	4	1	2

The biggest percentage increase of scratch width was observed in case of wood covered with wax, and the smallest one - in case of wood finished with contemporary oil and wax oil.

The manner of wood surface finishing has the biggest impact on scratch width in case of the smallest forces. With stronger forces, the impact of surface finish on scratch width decreases.

Scratch width depends on the sampling point; the smallest values were observed in the samples taken from the internal room corner and then from the traffic path. The widest scratches occurred in oak and elm wood samples taken from the external corner of the room (Fig. 3 and 6).

CONCLUSIONS

1. In case of scratch width difference at the 1-2 N force between wood with and without finish, the factors of finish kind and climate are significant. In case of scratch width difference at the 3-5 N force, only the climate factor is significant.
2. Significant differences for oak from Room no. 4 in Tarnowiec exist only between the "traffic paths" and "external" climates at the 1 N force. In case of elm from Room no. 5 in Tarnowiec, there are significant differences between the "internal" and "traffic path" climates, as well as "internal" and "external" at the 1-2 N force. In case of scratch width difference at 3-5 N force between elm wood with and without finish, the differences between samples from the "traffic path" climate and other climates in the Room no. 5 of the Tarnowiec Manor House are significant.
3. Detailed comparisons as to the kind of finish prove that the biggest difference in scratch width at 1-2 N force between wood with and without finish took place in case of wax finish, and the smallest one – in case of oil. Differences between all the finish kinds are significant at 1 N force. At 2 N force the differences between wax and varnish are not significant.

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Streszczenie: *Wpływ sposobu wykończenia powierzchni podłóg drewnianych na ich odporność na zarysowania*. Badania właściwości tradycyjnych powłok wykończeniowych podłóg drewnianych dotyczyły zmian odporności na zarysowania próbek niewykończonych oraz pokrytych woskiem, pokostem (naturalnym olejem lnianym) oraz jednocześnie współczesnym syntetycznym olejem posadzkarskim i olejowoskiem. Badaniom poddano próbki drewna zabytkowego pochodzące z posadzek kilku dworów południowo-wschodniej Polski i drewna współczesnego. Badania odporności na zarysowanie wykonano w oparciu o normą PN-EN 438-2:2005. Norma ta stosowana jest do badań powłok i nie jest precyzyjnym narzędziem dla badań niewykończonego drewna. Według niej wszystkie badane próbki znalazły się w jednej grupie, ponieważ uzyskano ciągłe zarysowania już dla siły 1 N. Rozbieżności w stopniu zarysowania były jednak wyraźne dla różnych gatunków drewna oraz dla drewna współczesnego i zabytkowego. Dlatego wyniki zostały wyliczone jako szerokość zarysowań. Za czynniki mające wpływ na właściwości drewna przyjęto: gatunek drewna, pochodzenie (dwór oraz pomieszczenie) oraz położenie elementów posadzkowych w pomieszczeniu, przekładające się na intensywność użytkowania elementu oraz warunki klimatyczne, w jakich drewno przebywa.

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