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DECORATIVE PROPERTIES OF WOOD SURFACE FINISHING WITH OILS AND HYDRO OILS

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ABSTRACT

Due to governing trends, emphasizing the natural beauty and the texture of the substrate in wood surface finishing attracts a lot of attention. Different coatings are used for this purpose. In addition to traditional penetrating materials such as oils, waterborne-oil coatings giving the effect of untreated wood have been developed (hydro oils). In this research we investigated the decorative properties of the samples of beech (*Fagus sylvatica* L.) and walnut wood (*Juglans regia* L.) coated with oils and waterborne-oil coatings. The higher color change (ΔE) was obtained when the samples were coated with oils, compared to the samples coated with hydro oils for both wood species. After oil application, samples of both wood species had a noticeably higher degree of gloss, while samples coated with hydro oil showed lower gloss values than untreated wood (for both wood species). The change in gloss of samples after coating was related to increase/reduction of surface roughness of the samples.

Keywords: wood, oil, hydro-oil, surface finishing, color, gloss.

1. INTRODUCTION

Very often, customers opt for a certain type of furniture based on the decorative properties of the coated surfaces: color, gloss and texture. By applying transparent coatings, the texture of the wood surface remains visible, which is most often preferred by customers who appreciate natural materials. Although transparent coatings do not contain pigments, they still slightly change the color of the wood surface to which they are applied. The degree of color change, as well as gloss, of coated wood surface depends primarily on the coating formulation. For instance, it is known that oil coatings give a „warmer color tone“ of the coated surface in comparison to untreated wood, while in case of water-based coatings the intensity of color change depends greatly on the color of the wood. Wood maintains its natural color tone when water-based coating is applied on the surface of brighter wood species, while giving "washed out" look when applied onto the surface of darker wood species (Flexner, 2010). In comparison to solvent-based coatings, water-based coatings give a lower “grain accentuation” on the wood surface (Prieto and Kiene, 2018).

Modern wood coatings are expected to be environmentally friendly. This category of materials includes coatings that have a lower proportion of volatile organic compounds

(VOC). Reduction in the VOC can be achieved by replacing harmful solvents with those that are innocuous or less harmful to the environment. In water-based coatings the great percentage of organic solvents is replaced by water. One of the main disadvantages of water-based coatings is the roughening of wood surface as a result of the wood fibers swellings in contact with water (Palija et al. 2013; Flexner 2010). Higher surface roughness generally leads to lower gloss. In order to minimize grain raising additional technological operations are usually needed (e.g. sanding with finer grit size or wetting the surface before coating). In addition to water-based coatings, oils and waxes are used as environmentally friendly materials. Due to their unique combination of transparency, sheen and texture, wood surface finishing with oils is highly appreciated for emphasizing the natural character of wood (Arminger et al., 2020). These traditional materials nowadays have modified formulations that enable greater resistance to various agents of the coated surface and greater durability of decorative and protective properties. The main advantage of these materials is that they penetrate into the substrate leaving very thin, barely visible layer of coating on the wood surface, making the surface pleasant to touch. In addition, an important feature of oil-coated surfaces is that damaged areas can be partially repaired, without removing the entire film of the coatings. Oil formulations usually contain wax, which reduces the shine of the coated surface. The non-optimal chemical resistance and water resistance of oil-coated wood surfaces is significantly improved by hydrophobisation with waxes (Prieto and Kiene, 2018).

Relatively new wood surface finishing materials (usually found by the name "hydro oils" on the market) combine the advantages of oils and water-based coatings. These water-based materials containing oils, due to their low viscosity, penetrate mostly into the substrate but also form a film with emphasizing matting effect, giving the impression of an untreated surface when applied on wood.

2. MATERIAL AND METHODS

The samples of beech (*Fagus sylvatica* L.) and walnut wood (*Juglans regia* L.) with dimensions 400x300x20 mm were used. From each wood species 10 samples were prepared, having thus a total of 20. Moisture content of wood was determined based on 5 measurements using a moisture meter with pins (model RVD-904, manufacturer Nigos, Serbia). The measured moisture content was 9.3% for walnut samples and 10.1% for beech samples, which is in accordance with the recommendations for the interior use of wood.

The samples were cut lengthwise into two equal parts (200x300x20mm) and sanded on a narrow-belt sander using grit size P80 and P120. Just before application of the coating, the samples were hand sanded using block with sanding paper grit size P180, in order to obtain a clean and fresh surface, which is a prerequisite for good adhesion of the coating.

Half of the samples of both wood species were coated with oils (4951-HW, manufacturer Borma Wachs, Italy), while the other half were coated with 2K hydro oils (YS-M009 / -T94, manufacturer Renner, Italy; hardener YC M403 manufacturer Renner, Italy). The main physical characteristics of the applied materials are given in technical sheets (Table 1):

Table 1. *Main physical characteristics of used coatings: oils and hydro oils*

	oil	**hydro oils**
Solid content (%)	45±2	25±1
Density (g/cm^3)	0,87 ± 0,02	1,010±0,020
Viscosity DIN 4 (s)	19±2	16±3

After the sanding of the samples, the color and gloss was measured before and after surface finishing (4 measurements per sample, 80 before and 80 after coating). Measurement of the surface roughness was done at the same measuring points used for determination of gloss and color. Since it is a common knowledge that the properties of coating depend particularly on the chemical composition and film thickness of the coating (Pavlič, Petrič, Žigon 2021), the dry film thickness of the coating was measured. In addition, the surface roughness of the samples was measured before and after surface finishing, in order to get more information about the differences in the decorative properties of individual combinations of wood species and coatings.

Both materials (oils and hydro-oils) were applied by brush in a regime that was in accordance with the manufacturer's recommendations. The oil was delivered prepared, and was thoroughly mixed before application. Coating consumption was 79 g/m^2, based on measurements of samples weight before and after application of coating. The surface finishing using oils was done in the following order: application of the first layer of coating, drying for 24h, intermediate sanding using sanding paper grit size P240, application of the second layer of coating and drying for 24h. Sanding was done manually by means of a sanding blog of the required grit size.

Hydro oil was prepared by adding 5% of hardener and stirring until uniform consistency was reached. Coating consumption was 90 g/m^2, based on measurements of samples weight before and after coating application. The surface finishing using hydro oils was done in the following order: application of the first layer of coating, drying for 3h, intermediate sanding with sanding paper grit size P240, application of the second layer of coating and drying for 48h.

Measurement of dry film thickness of the coating was performed by ultrasonic gauge (model PosiTector 200, manufacturer DeFelsko, USA) without destruction of the coating, in accordance with SRPS EN 2808: 2019. The dry film thickness was measured on each of the coated samples (Figure 1), making a total of 40 measurements.

Figure 1. *Determination of dry film thickness of coating by ultrasonic gauge*

Measurement of the color of the surface of the samples before and after finishing was performed using a color measuring device (model EasyCo 566, manufacturer Erichsen, Germany). The instrument works in the CIELab system expressing color by 3 coordinates: *L*, *a* and *b*. Parameter *L* presents the color brightness, parameter *a* presents the red-green component of the color, and parameter *b* presents the yellow-blue component of the color. The color change is calculated according to the formula:

$$\Delta E = \sqrt{(L_2 - L_1)^2 + (a_2 - a_1)^2 + (b_2 - b_1)^2}$$

Where:

• Δ*E* - difference in wood color after surface finishing with coatings
• L_1, a_1, b_1 - parameters of the color of the uncoated wood samples
• L_2, a_2, b_2 - parameters of the color of the coated wood samples

Measurement of the surface gloss of samples before and after surface finishing was performed using a glossmeter (model Novo Gloss Trio, manufacturer Rhopoint instruments, UK) in accordance with SRPS EN 13722: 2004, figure 2. Since the measured values of gloss of coated and uncoated samples were mainly bellow 10GU (measured at an angle of incidence of 60 º), for the improved resolution of low gloss the angle of incidence of 85º was used, as recommended in the standard mentioned.

Figure 2. *Determination of gloss by glossmeter*

A stylus contact tester (model TR200, manufacturer TIME Beijing High Technology) was used to measure the surface roughness of the samples, figure 3. The instrument works in accordance with ISO 4287:1997. The sample length was 2.5 mm, and the number of sample lengths was 5. The instrument is equipped with a needle with a diamond tip having a diameter of 5 µm.

Figure 3. *Measurement of surface roughness of samples by stylus method*

The following surface roughness parameters were measured:

- R_a - Arithmetic mean deviation of the assessed profile;
- R_z - Mean height of profile element
- R_t - Total height of profile

3. RESULTS AND DISCUSSION

The results of the dry film thickness of the coatings are given in Table 2.

Table 2. *Dry film thickness of oils and hydro oils on beech and walnut samples*

Wood species	**beech**		**walnut**	
Coating type	oil	hydro oil	oil	hydro oil
Dry film thickness of coating (μm)	26.5	40.5	28	27.4

On beech samples, the film thickness of coating measured on the samples coated with hydro oils was higher by 52.7% compared to the samples coated with oils. Significantly lower values of dry film thickness (by 32.4%) of hydro oils were measured on walnut samples compared to beech samples. This can probably be related to anatomical and physical differences in these two wood species. Slightly lower density of walnut wood in comparison to beech wood (640 compared to 680 kg/m^3, in absolutely dry condition, respectively) could lead to less swelling and thus less narrowing of the pores, i.e. potential paths for the coating penetration, so that most of the applied material remains on the wood surface. This is confirmed by a marginally higher volume porosity of walnut wood (57%) compared to beech wood (55%) (Šoškić and Popović, 2002). In addition, beech wood is characterized by strong tendency to swell (volume swelling is 17.6% compared to 13.9% for walnut). In previous research (Palija, Jaić, Jaić 2013) it was concluded that swelling of the fibers in the surface layer of the wood leads to an increase in thickness of the water-coated films.

The results of wood surface color before and after finishing with oils and hydro oils are given in Table 3.

Table 3. *Color of beech and walnut samples uncoated and coated with oils and hydro oils*

Wood species		**beech**				**walnut**			
Coating type		oil		hydro oil		oil		hydro oil	
Surface finishing		uncoated	coated	uncoated	coated	uncoated	coated	uncoated	coated
Color parameter	*L*	66.11	63.94	66.15	63.64	51.07	47.32	49.72	47.36
	a	8.12	9.67	8.01	8.85	6.51	6.93	6.24	6.49
	b	15.03	20.28	15.12	16.32	13.97	14.35	12.96	13.29
	ΔE	5.89		2.94		3.79		2.43	

When comparing wood species, a greater color change occurs on lighter species (beech) after surface finishing with both coating, which is in line with the results of previous studies (Szczuka, Rozanska, Korycinsk 2016). In terms of coating type, the higher color change is noticed when the oils were applied. The color change is twice higher (increase by 102% for beech samples coated with oils compared to hydro oil). The slightly smaller color change of the walnut samples after coating with oils (57% compared to samples coated with hydro oils) was most likely result of the darker color tone of untreated wood compared to beech samples. By applying hydro oil, the color tone of coated wood is very similar to the uncoated one, giving the impression of untreated wood, which is one of the main features of this coating.

Table 4 shows the results of gloss measurements on beech and walnut samples before and after surface finishing with oils and hydro oils.

Table 4. *Gloss of beech and walnut samples uncoated and coated with oils and hydro oils*

Wood species	**beech**				**walnut**			
Coating type	oil		hydro oil		oil		hydro oil	
Surface finishing	uncoated	coated	uncoated	coated	uncoated	coated	uncoated	coated
Surface gloss	5.77	27.84	6.22	2.73	6.78	33.51	7.52	3.19

In terms of wood species, uncoated walnut samples showed a significantly higher degree of gloss (by 19.3%) compared to beech samples ($t(77) = -2.971$, $p < 0.05$), which can be explained by differences in anatomical structure. Walnut wood has diffusely porous-semi-ringed porous while beech has diffusely porous structure (Vilotić, 2000).

When using oils, the difference in gloss of the coated surface of beech and walnut samples was not statistically significant ($t(38) = -5.445$, $p > 0.05$). This is consistent with the results of the previous research of the gloss of coated surface using conventional coatings and UV polyacrylic coatings with nanoparticles (Kaygin and Akgun, 2009). In both wood species, the surface gloss was noticeably increased after application of oils, and lowered after application of hydro oils (in comparison to uncoated wood). The reason for this was the scattering of light on the surface that was coated with water-based oils coatings (hydro oils).

Wood species had statistically significant impact ($t(34) = -3.740$, $p < 0.05$) on the gloss of the surface coated with hydro oils, which can be related to distinction in film thickness of the coating and differences in anatomical characteristics that affect roughness of the coated samples in surface layer.

Table 5 shows surface roughness parameters R_a, R_z and R_t of beech and walnut samples before and after finishing with oils and hydro oils.

The surface roughness of walnut samples after sanding was significantly higher in relation to roughness of sanded beech samples (8.2% higher value of parameter R_a; 30.3% higher value of parameter R_z, 53.9% higher value of parameter R_t, respectively). This difference in surface quality after the same sanding regime emphasizes the importance of the anatomical structure in the geometric irregularities of wood surface. However, the higher surface roughness of walnut samples led to lower gloss values. It can be related to the findings of the previous research (Salca et al., 2021) that correlation between surface roughness and gloss exists if the dominant effect influences the reflection originating from the surface structure.

Table 5. *Surface roughness parameters R_a, R_z and R_t of uncoated and coated beech and walnut samples with oils and hydro oils*

Wood species		**Beech**				**Walnut**			
Coating type		oil		hydro oil		oil		hydro oil	
Surface finishing		uncoated	coated	uncoated	coated	uncoated	coated	uncoated	coated
Surface roughness		3.168	1.947	3.344	4.592	3.462	2.131	3.583	3.613
	R_z	25.86	14.99	25.92	32.35	32.43	20.35	35.02	33.42
	R_t	35.10	20.57	35.20	42.47	53.48	36.95	54.71	52.88

After application of the oils, surface roughness of the samples of both species decreased, which can be explained by formulation of oil that does not contain ingredients that cause swelling, and thus the lifting of the fibers is negligible. On the other hand, hydro oils contain a large proportion of water, which causes wetting and swelling of the wood and lifting of the fibers in the surface layer. In contact with water the wood fibers that were left imprinted during sanding process lift and thus increase the surface roughness.

Surface roughness of walnut samples after coating with hydro oils remained unchanged which is seemingly unexpected. This may be the result of the filling of the open tracheids in surface layer of the wood with a coating, which could diminish the "anatomical roughness" of the walnut samples. Filling the surface structural depressions can be the reason for obtaining lower values of film thickness and higher values of gloss in walnut samples coated with hydro oils. Parameters R_a and R_t show the differences in surface quality between samples of beech and walnut wood coated with hydro oils. In previous research (Jaić, Palija, 2015) surfaces roughness parameters R_a and R_z were recommended for characterization of roughness of the coated surfaces, based on the high correlation between above parameters and the gloss of coated samples. In accordance with this recommendation, lower values of gloss of beech samples coated with hydro oils in comparison to walnut samples, may be attributed to higher values of R_a of coating surface (27.1% higher values on beech samples).

The increase in wood surface roughness after oils application is higher in walnut samples than in beech samples (9.4% higher value of parameter R_a; 35.7% higher value of parameter R_z, 79.6% higher value of parameter R_t, respectively), for the equal dry film thickness of the coating. With relatively small dry film thickness of the coating, the roughness of the substrate was telegraphed on the surface layer of the coating. However, the stated difference in roughness did not affect the gloss values of the coated samples.

4. CONCLUSIONS

Based on the results the following can be concluded:

• Decorative characteristics of coated wood surface depend strongly on the coating type and the wood species. Beech samples, as a lighter wood species (in comparison to walnut samples), had greater color change after surface finishing with both coatings. Surface finishing with oils had a higher effect on the color change of wood samples in comparison to surface finishing with hydro oils. The low intensity of color change using hydro oils (ΔE = 2.94 for beech samples; ΔE = 2.43 for walnut samples) gives the impression of untreated wood, which confirms one of the main features of this type of material.

• By application of oils and hydro oils the decorative properties of wood samples changed: the surface roughness reduced and the gloss increased when oils were used, while the use of hydro oils lowered the wood surface gloss in samples of both wood species and increased the surface roughness of beech samples compared to untreated wood.

• The film thickness of the water-based coating appreciably depends on the type of wood substrate. Considerably lower values of dry film thickness of hydro oils (by 32.4%) were measured on walnut samples compared to beech samples.

REFERENCES

[1] Arminger, B., Jaxel, J., Bacher, M., Gindl-Altmutterc, W., Hansmann, C (2020): On the drying behavior of natural oils used for solid wood finishing, Progress in Organic Coatings 148: 105831.

[2] Flexner, B (2010). Flexner on Finishing. Steve Shanesy, UK.

[3] ISO 4287:1997 Geometrical product specifications (gps)– surface texture: Profile method — Terms, definitions and surface texture parameters
[4] Jaić, M., Palija, T. (2015): High gloss finish: the impact of surface roughness on gloss. Zaštita materijala, 56 (4):457–462.
[5] Kaygin, B., Akgun, E. (2009): A nano-technological product: An innovative varnish type for wooden surfaces. Scientific Research and Essay, 4 (1):1–7.
[6] Palija, T., Jaić, D., Jaić, M. (2013). “Uticaj bajcovanja drveta trešnje (*Prunus Avium* L.) na adheziju premaza.” Zaštita Materijala 4: 396–403.
[7] Palija, T., Vučković, A., Jevtić, P., Jaić, M. (2013): The Impact of Wood Staining on the Adhesion of Certain Types of Coating.” In 24th International Scientific Conference ”Wood is good - user oriented material, technology and design, 111–19. Zagreb.
[8] Pavlič, M., Petrič, M., Žigon, J. (2021): Interactions of Coating and Wood Flooring Surface System Properties.” Coatings 11 (1): 1–13.
[9] Pelit, H., Budakçi, M., Sönmez, A., Burdurlu, E. (2015): Surface roughness and brightness of scots pine (Pinus sylvestris) applied with water-based varnish after densification and heat treatment. Journal of Wood Science, 61: 586–594.
[10] Prieto, J., and Kiene, J. (2018): Wood Coatings: Chemistry and Practice, Vincentz Network, Hanover, Germany
[11] Šoškić, B., Popović, Z. (2002): Svojstva drveta, Univerzitet u Beogradu, Šumarski fakultet, Beograd, Srbija
[12] SRPS EN 13722:2009 - Furniture - Assessment of the surface gloss
[13] SRPS EN ISO 2808:2019- Paints and varnishes -- Determination of film thickness.
[14] Salca, E.-A., Krystofiak, T., Lis, B., Hiziroglu, S. (2021): Glossiness evaluation of coated wood surfaces as function of varnish type and exposure to different conditions. Coatings, 11(5): 1–14.
[15] Szczuka, M., Rozanska, A., Korycinsk, W. (2016): Selected Aesthetic Properties of Traditional Finish Coatings Used in Furniture Making Selected Aesthetic Properties of Traditional Finish Coatings Used in Furniture Making.” Annals of Warsaw University of Life Sciences - SGGW Forestry and Wood Technology, 96: 168–175.
[16] Vilotić, D. (2000). Uporedna anatomija drveta, Univerzitet u Beogradu, Šumarski fakultet, Beograd, Srbija

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