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Nickel plating on wood and wood composite surfaces: Characterization of surface durability

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Abstract: In this study, the performance of nickel plating on wooden surfaces was investigated. Black pine (BP), medium density fiber board (MDF) and particle board (PB) were used for the wooden samples. After the sample surfaces were sanded with 200, 500 and 1000 grit sandpaper and varnished with polyurethane varnish (150 g/m^2), they were nickel plated using a spray gun and compressed air. After drying the samples at room temperature for 72 h, scratch analyses were performed according to TS EN 15186 (2012) and TS EN ISO 2409 (2020) and abrasion analyses were performed according to TS EN 13329 +A. The staining resistance of the samples was determined according to the DIN 53799 standard. According to the results, surface strength of the MDF samples was lower than those of PB and BP. The scratch analysis results for the black nickel coating were lower than those for TS EN 15186 (2012). However, it was higher according to TS EN ISO 2409 (2020) scratch analysis. In terms of stain resistance, all samples were found to be resistant to water, soap, tea, and acetone stains, except for coffee stains. Upon visual examination, a slight coffee stain was observed on the sample surfaces. As a result, in the light of surface strength analysis, it was concluded that the surfaces of wooden boards are not suitable for nickel plating.
Keywords: Nickel coating, Stain resistance, Black pine, Abrasion analysis, Scratch analysis

Ahşap ve ahşap kompozit yüzeylerde nikel kaplama: Yüzey dayanıklılığının karakterizasyonu

Özet: Bu çalışmada, ahşap yüzeylere nikel kaplama yapılmış ve kaplamanın performansı incelenmiştir. Odun örnekleri olarak karaçam (BP), orta yoğunlukta lifli levha (MDF) ve yonga levha (PB) kullanılmıştır. Numune yüzeyleri 200, 500 ve 1000 grit zımpara ile zımparalandıktan ve poliüretan vernik (150 g/m^2) ile verniklendikten sonra püskürtme tabancası ile basınçlı hava kullanılarak nikel ile kaplanmıştır. Numuneler oda sıcaklığında 72 saat kurutulduktan sonra TS EN 15186 (2012) ve TS EN ISO 2409 (2020) 'a göre çizilme, TS EN 13329+A'ya göre aşınma analizleri yapılmıştır. Örneklerin lekelenme direnci DIN 53799 standardına göre belirlenmiştir. Elde edilen sonuçlara göre, MDF örneklerinin yüzey dayanımlarının PB ve BP numunelerinden daha düşük olduğu tespit edilmiştir. Siyah nikel kaplama için çizilme analiz sonuçları TS EN 15186 (2012)'ya göre daha düşük, ancak TS EN ISO 2409 (2020)'a göre daha yüksek çıkmıştır. Lekelenme direnci açısından kahve lekeleri dışında tüm numunelerin su, sabun, çay ve aseton lekelerine karşı dayanıklı olduğu tespit edilmiştir. Görsel incelemede numune yüzeylerinde hafif bir kahve lekesi gözlenmiştir. Sonuç olarak yüzey dayanım analizleri ışığında ahşap levhaların yüzeylerinin nikel kaplamaya uygun olmadığı sonucuna varılmıştır.
Anahtar kelimeler: Nikel kaplama, Leke direnci, Karaçam, Aşınma analizi, Çizilme analizi

1. Introduction

Wood is a unique polymer composite that can be used both indoors and outdoors. However, in order to make wood suitable for industrial applications, it needs to undergo a refining process that involves the use of additives (Rowell, 2012; Gérardin, 2016). These additives can include protective coatings, preservatives, plastics, and more (Rowell, 1984; Hon, 2006). When wood is used outside, it is exposed to a variety of agents, making protection essential. This protection can be obtained by using coatings or modifications, which can be accomplished through surface or bulk treatments. (Papadopoulos and Taghiyari, 2019).

Substrates are coatings that are applied on wood surfaces and serve both a conservative and decorative purpose. Lacquers, varnishes, and paints are some coatings used on wood surfaces. The main components of a coating, which include pigments, binders, fillers, solvents, and additives, determine its properties (Sandberg, 2016). Nanotechnology has the potential to enhance wood strength such as durability, mechanical properties, water absorption, fire resistance and UV absorption (Wegner et al., 2005; Wegner and Jones, 2006; Sandberg, 2016).

The quality of a finished product is often evaluated based on the glossiness of its surface, which is determined by the reflection of incident light from various directions (Ged et al., 2010; Vardi et al., 2010). High-gloss surfaces are in high demand by manufacturers, while matte finishes remain popular in certain solid wood furniture markets. While reflection structure images have been improved as an

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alternative technique to visually depict gloss in high-gloss composite products (Ettwein et al., 2017), recent research has also highlighted the appeal of both coated and uncoated surfaces of wood products (Demirkir et al., 2014; Ikei et al., 2017).

In fact, a model for creating innovative, qualitative, and ecologically friendly wooden furniture products has been validated. These products offer comfortable and reliable solutions while remaining environmentally sustainable (Demirkir et al., 2014; Salca et al., 2017).

Under the same machining conditions, the roughness of two sections within an annual ring can differ, leading to irregular reflections of the wood's properties (Csanady et al., 2015). During the machining process, the wood grain may raise, twist, and lift, which can have an impact on the final surface quality during finishing (Richter et al., 1995; Sönmez et al., 2011). The surface quality of wood has a direct effect on its glossiness (Demirci et al., 2013; Bekhta et al., 2014), and there may exist a correlation between surface gloss and roughness, especially. When the primary factor affecting the reflection is the surface structure of the wood unit (Salca et al., 2021).

The reflection properties of wood can be altered by different resin clear coatings, depending on the coating thickness (Csanady et al., 2015). Transparent coatings are favored for preserving the natural wood color and enhancing its brightness, although they exhibit reduced long-term stability compared to pigmented coatings, which are more resistant to sunlight (Evans et al., 2016; Cogulet et al., 2018; Pánek et al., 2020). Nevertheless, transparent coatings remain popular, and different levels of brightness can be obtained by using different varnish types and application systems (Salca et al., 2016, 2017; Slabejová et al., 2016). Alternative ecological products, such as water-based and UV varnish, have gained popularity in recent years because of their low emissions, quick application, and good brightness retention. Water-borne coatings, on the other hand, may take longer to cure and penetrate because of their lower water absorption (Kesik and Akyildiz, 2015).

To ensure abrasion and chemical resistance, volatile organic compounds (VOC) regulations are applied to interior coatings (Philipp, 2010). VOC emissions from indoor materials and finishing products continue to be a source of concern in indoor air quality studies (de Gennaro et al., 2015, Palmisani et al., 2020), and the acceptable concentration range of total VOCs in the air for human health is between 0.3 and 0.5 mg/m^3 (de Gennaro et al., 2015).

Previous studies have investigated the resistance of wooden flooring and horizontal furniture parts to different chemicals. These elements are highly exposed in interiors, making their chemical resistance an important factor (Williams, 1999; Nejad et al., 2013; Vidholdová et al., 2021). To evaluate the chemical resistance of coatings on lignocellulosic materials, a rating scale is frequently utilized in standard procedures and testing (Salca et al., 2021). While oils can enhance the natural appearance of wood, they 9, offer limited resistance to various chemicals (Bulian and Graystone, 2009). However, no significant differences in cold liquid resistance, such as ethanol, coffee, water, paraffin oil or red wine, were determined for oak parquet coated with different coatings. Properties of the topcoat used have an effect on the resistance to cold liquids (Pavlič et al., 2021).

Wang and Liu (2011) investigated a process for preparing electroless nickel plated wood veneers for electromagnetic interference (EMI) shielding using chitosan. The process involves chemically adsorbing Pd (II) ions on chitosan-modified wood surfaces, reducing them, and initiating Ni-P co-deposition in a plating bath (Figure 1). They were characterized by SEM-EDS and XRD and reported that the surfaces coated with 1.8 wt % phosphorus and 98.2 wt % nickel were uniform, compact, and continuous. The plated birch veneers exhibited good electromagnetic shielding effectiveness of over 50 dB in the frequency range from 10 MHz to 1.5 GHz, as well as electro-conductivity with a surface resistivity of 0.24 $\Omega \cdot cm^{-2}$.

In general, many surface modification techniques are used to produce Ni-based coatings. Among these, laser coating is very effective. So far, researchers have used gas tungsten arc coating, plasma spraying, laser coating, thermal spraying, high-speed oxygen fuel spraying (HVOF), electrodeposition, electroplating, electroless plating, electrophoretic deposition (EPD), detonation spraying, etc. in the development of Ni-based metal matrix composite coatings. They used various methods such as cold spraying, hydrothermal deposition and packaging (Karmakar et al., 2021). In this study cold spraying method was used to coat on wood surface. Wood surface was coated by using liquid polyurethane varnish which was sprayed on the surface. Nickel coating process was applied on this layer not directly on wood surface. $NaBH_4$ Solution was sprayed on varnished layer and activated for nickel (N^{+2}) ions. Following stages were introduced in method section.

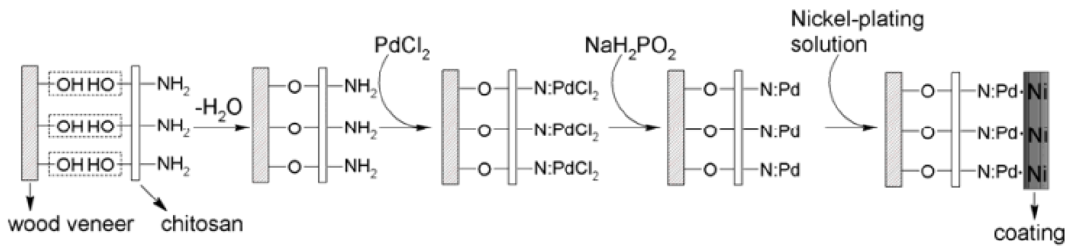


Figure 1. Proposed mechanism of the activation and plating process (Wang and Liu, 2011)

There is a wealth of research that has been conducted on modified wood, as evidenced by numerous citations (Nagasawa and Kumagai, 1989; Li-juan et al., 2005; Li et al., 2010; Shi et al., 2017). In recent years, there has been a growing number of articles published that explore the use of electroless nickel plating and its alloys as a means of improving wood properties for a variety of applications (Jintian and Guangjie, 2004; Liu et al., 2010; Sahoo and Das, 2011). Specifically, researchers have investigated the use of this technology to enhance wood's electrical conductivity and electromagnetic shielding effectiveness. These studies represent an exciting development in the field of modified wood and have the potential to open up new avenues for wood usage in diverse industries (Bakraji et al., 2001; Li-juan et al., 2005; Wang et al., 2006, 2011). However, research on electroless nickel coatings on beech wood is limited, and the impact of multiple electroless nickel coatings on beech wood has yet to be reported (Amer, 2014).

In this study, the surfaces of MDF, PB, and solid wood materials have been nickel-plated. The nickel plating was carried out using a spray method. The nickel-plated surfaces were coated with colored varnish to obtain glossy surfaces in different colors. Nickel plating is typically applied to the surfaces of materials such as metal and plastic. Occasionally, it is also applied decoratively to small wooden surfaces such as furniture legs, picture frames, and wooden ornaments. However, a few studies have been found in the literature on nickel plating on large surfaces such as wooden panels. Nickel-plating application on the surfaces of kitchen cabinet doors, which are highly valued by women, has not been encountered. This study evaluates the possibilities of nickel plating on boards such as solid wood, PB, and MDF used in the furniture sector. The aim of this study is to create a hard, glossy, and colorful surface on composite boards. There is increasing demand for boards with hard and glossy surfaces in the furniture sector. This study evaluates the possibilities of meeting this demand by nickel plating the surfaces.

2. Material and methods

2.1. Materials

In the study, MDF, PB and solid BP wood were used as wood material. Polyurethane varnish was used as the primer varnish before the nickel coating. Varnish was purchased from local market. Other coating solutions were purchased as a set from DGN company. The solutions are numbered between 1-5 because nickel plating products are taken as a set.

Preparation of samples

The wood board surfaces were first sanded with 200 grits, then 500 grit and finally 1000 grit sandpaper. After the surfaces were cleaned of dust and dirt, nickel plating process were carried out in the following.

The initial varnish process was first applied to the surfaces of the woods. This process was carried out with a spray gun with an air pressure of 5 bar. In this process, 150 gr of polyurethane varnish was used per 1 square meter. After the boards were kept for 72-hour, oil remover (NaOH solution) was applied to the surface of the bords using spray method as 200 gr per square meter. The surface was washed with water after 1-2 minutes. The washing process was continued until the water droplet reached a level that could not hold on to the surface. A smooth surface was obtained. NH_4Cl solution was applied on surface with a spray gun because of activating the surface. Then, surface was washed with water. After the washing process, the surface is completely shiny and if there was no gap on the surface, the next treatment was started before the surface dried. sodium silicate (Na_2SiO_3) solutions (it was known liquid glass) and rhenium alloy (W-Re) solution were applied together. Two chemicals were sprayed equally on sample surface with an air gun from a distance of approximately 40-50 cm, at an angle to contact each other in the air. The samples were fixed in a vertical position so that it might be applied from the bottom up and the liquid flowed down completely. The application was completed as quickly as possible. The sample surface area was washed evenly.

Oil remover NaOH was applied. It was sprayed in a small amount in the form of small particles from 50-60 cm. Surfaces were distilled with water. Washed evenly. Afterwards, 1 liter of water was poured onto the surface. Samples were dried with an air compressor so that no water particles were left on it. After the process was done, it was left to dry for 6-8 hours in an environment where it would not be dusty. After drying, 2k acrylic resin was applied on samples surfaces as the top protector. It was sprayed from 30-40 cm in a single coat covering all areas. In order to get a good result, great attention has been paid to the correct application of this step. At this stage, support was received from an experienced person in paint application. The top protective resin is left to dry in the open air for 72 hours.

2.2. Methods

2.2.1. The abrasion test

The abrasion test is a common method utilized to evaluate the durability of material surfaces when subjected to mechanical stress, particularly abrasive stress. This method is frequently applied to finished laminates commonly used in worktops and flooring to protect printed patterns from wear and tear over time. To conduct the test, the DIN EN 13329 (2021) standard was followed, and the Taber Abraser device was used. The test specimen was divided into four quadrants and attached to the device, and calibrated sandpaper was affixed to abrading wheels of specific weight. The wheels were then rotated at a constant speed, with the sandpaper renewed after 200 cycles or as needed. The initial abrasion point was reached when worn-down spots of at least 0.60 mm^2 in area appeared in two quadrants. When the equally large spot appeared in a third quadrant it was final abrasion point under normal usage.

2.2.2. Abrasion analysis degree evolution

The initial point (IP) was determined by rounding up the number of revolutions at which it occurred to the nearest 100 cycles, and the average of three measurements was calculated to determine the material's resistance to abrasion or wear. The IP values allowed for the classification of sample into five different abrasion or wear classes, indicating their respective levels of durability and suitability for various applications (Table 1). The tests were conducted in controlled environments to ensure consistency and accuracy (TABER, 1994).

Table 1. Abrasion classes

Abrasion class (acc. to DIN EN 13329)	ACI	AC2	AC3	AC4	AC5
Average IP value from the specimens	900	1.800	2.500	4.000	6.500

2.2.3. Scratch analysis

A- Universal scratch tester 413

Scratch analysis involves a uniform testing procedure that applies to all relevant test methods. The sample was affixed to a rotating platform with a standard rotation speed of 5 min^{-1}. A load arm with a test tool of fixed dimensions was utilized to apply pressure on the sample, with the applied pressure level being adjustable between 0-10 N (in 0.1 N increments) or 0 - 1 N (in 0.01 N increments). The examination of the sample's resistance to this pressure was determined visually by inspecting the score mark, with comprehensive instructions provided in the operational instructions' manual (TS EN 15186, 2012).

Scratch degree evolution

In order to obtain the score mark values of the samples, the following steps were carried out:

1. The samples were visually examined under a 70-watt fluorescent white light.
2. The sample was positioned at eye level, at a distance of 1 meter from the eye.
3. The sample was observed at a 45-degree angle.
4. Whenever a complete circular scratch was visible under the light, the corresponding newton value was recorded as the score mark value (TS EN 15186, 2012).

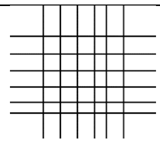
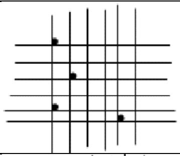
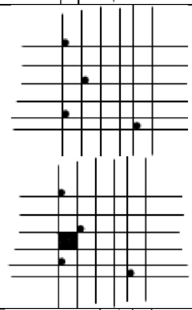
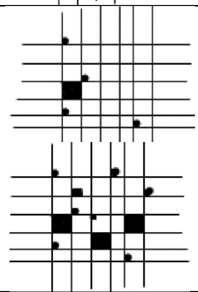
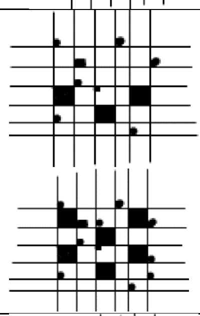
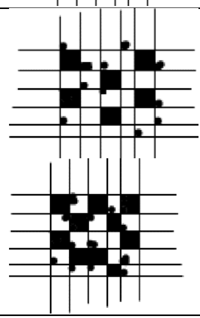
B- Cross-cut test (TS EN ISO 2409)

This experimental procedure is designed to assess the ability of paint coatings and varnishes, including wood stains, to resist detachment from a substrate when subjected to a perpendicular grid pattern cut that penetrates into the substrate. While this test procedure can provide valuable information related to the adhesion of the coating to either the substrate or the previous coating, as well as other relevant factors. It should not be relied upon as a definitive tool for measuring adhesion. Instead, this procedure serves as an empirical test method that can be used to evaluate the resistance of paint coatings and varnishes to detachment under specific conditions (TS EN ISO 2409, 2020).

2.2.4. Evolution

Perpendicular grid pattern that penetrates into the substrate was examined by eyes. The percentage of the deformed area was determined, and the surface strength was decided according to Table 2.

Table 2. Grading of deformation according to DIN ISO norms (TS EN ISO 2409, 2020)

DIN /ISO norms.	Percentage of deformation	Cross-cut applied area
GT:0	0 %	
GT:1	0-5 %	
GT:2	5-15 %	
GT:3	15-35 %	
GT:4	35-65 %	
GT:5	100 %	

2.2.5. Stain resistance analysis

This method is employed to test the surface's sensitivity or resistance to different foreign substances, which is crucial for evaluating the durability of decorative surfaces against exposure to various substances like alkaline solutions, acids, and solvents, which can come into contact with laminated particle boards during daily use. The duration of surface exposure to the test substances is determined by their respective categories. This test assesses the surface's resistance to staining caused by these substances (DIN 53799, 1986).

The test involves applying substances such as lipstick or shoe polish, Faber-Castell lead pencils No. 129902 2B and 4B, and a laminated particle board at room temperature. A small amount of the test substance is applied to an area measuring at least 5 cm x 10 cm, and after a specific contact time, the graphite is rubbed off, the shoe polish is wiped off, and the surface is cleaned with ethanol-soaked filter paper. Lipstick has a contact time of 16 hours (DIN 53799, 1986).

It is crucial for decorative surfaces to resist any tendency to absorb foreign substances, which may appear as stains or dirt deposits. Moreover, open-pored surfaces (Figure 2a, b) need to be considered, where foreign particles can accumulate, making cleaning difficult. Although the test substances listed here are only examples, other substances may also be utilized to evaluate the surface's sensitivity or resistance to staining caused by chemical reactions (DIN 53799, 1986).

3. Results and discussion

3.1. Surface mechanical properties

The abrasion and scratching values of samples quite low. It is thought that the reason for this is due to the varnish applied on the surface. Because it was observed that the finish coat on nickel was completely removed when the edges of the samples were cut with a circular saw. The changes in wear and scratch values depending on the color were given in Table 3. It has been determined that the highest wear and scratches are in the nickel-plated coatings on the PB. Among the colors, the lowest wear and scratch values were obtained from BP nickel-plated coatings.

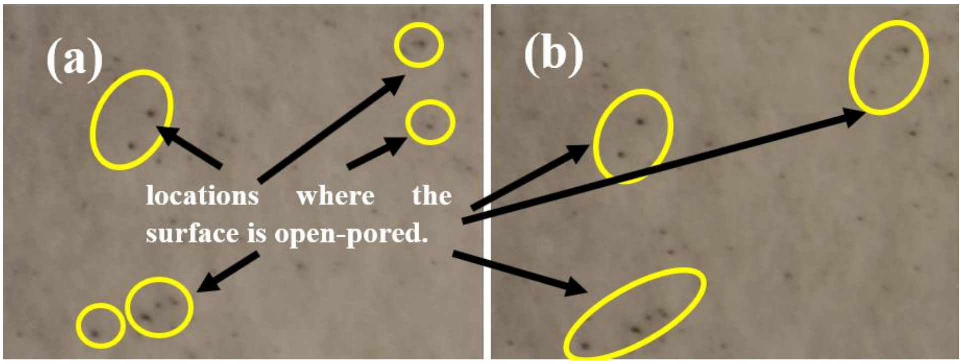


Figure 2. Decorative surfaces treated with graphite (a) and lipstick (b). The spots indicate locations where the surface is open-pored and substances were thus able to adhere (DIN 53799, 1986)

Table 3. Surfaces mechanical stress properties

Samples	Universal scratch tester (Newton) Sig: 0.01*	Taber abrasion resistance (rpm) Sig: 0.01	Cross-cut (visibility)
MDF1	0.021 (±0.01)** ab***	14 (±1) a	GT:0
MDF2	0.033 (±0.01) cde	18 (±1) b	GT:5
MDF3	0.034 (±0.01) cde	22 (±1) ef	GT:5
MDF4	0.031 (±0.01) c	20 (±1) cd	GT:1
MDF5	0.032 (±0.01) cd	21 (±1) de	GT:5
BP1	0.02 (±0.01) ab	15 (±1) a	GT:0
BP2	0.35 (±0.01) c	20 (±1) cd	GT:5
BP3	0.37 (±0.01) e	23 (±1) f	GT:5
BP4	0.03 (±0.01) f	21 (±1) de	GT:1
BP5	0.035 (±0.01) cde	22 (±1) ef	GT:5
PB1	0.019 (±0.01) a	19 (±1) bc	GT:0
PB2	0.024 (±0.01) b	19 (±1) bc	GT:5
PB3	0.03 (±0.01) c	21 (±1) de	GT:5
PB4	0.036 (±0.01) cde	25 (±0.5) g	GT:1
PB5	0.032 (±0.01) cd	23 (±1) f	GT:5

*Significant ($P < 0.05$), **Standard deviation (±), ***Duncan statistical analysis groups (a, b, c, d, e, f, g) (MDF: Medium Density Fiberboard, BP: Black Pine, PB: Particle Board, GT: Gathered Targed)

It was determined that the scratch values of all samples were between 0.020 and 0.037 in the results of the scratch analysis performed with the universal scratch tester. This value is quite low according to TS EN 15186 (2012). Also, cross-cut scratch test results were similar. Almost 100 % scratching occurred in all samples (Figure 3a, 3b, 3c, 3d) except for the black color (Figure 3e). It was determined that the protection varnish on the top surface did not fully adhere to the samples. The protective varnish was completely separated from the surface when the edges of the samples were cut with a circular saw. Nickel plating, which is under the protection varnish, is used to give a shine effect to the sample surfaces. Nickel coating has no effect on the scratch and abrasion resistance of the coating. Without the top protection varnish, the nickel coating is easily wiped off with a wet cloth.

It was observed that the primer varnish under the nickel coating made the samples very strong. As a result of the cross-cut scratch analysis, it was determined that the primer layer was at the GT:0 degree. This indicates that the scratch rate of the primer coating is close to 0 %. Considering that the nickel coating and the protective varnish on it are easily separated. It can be said that only the primer paint is more effective in protecting wooden surfaces. In addition, the cross-cut scratch analysis of the primer layer is considerably higher than the nickel-plating and protection varnish on it. According to these results, it can be said that nickel-plating does not provide any advantage on wooden surfaces.

In a study, beech wood surface layer was altered by using nickel metal as a catalyst to activate it. The activated surface was then electroless nickel coated using multiple baths separated by drying. SEM and X-ray diffraction were used to determine the thickness and structural properties of the nickel film, which revealed a thickness of 2.9-3 m and rapid growth of nickel crystallites with increasing number of depositions runs (Amer, 2014). This study was different than ours in terms of methodology because they coated wood surfaces by electroless nickel coating in many baths separated by drying at 100 °C during 24 h.

In a study Kanokwijitsilp et al. (2016) reported that a nanocomposite coating for wood was developed using colloidal silicon dioxide nanoparticles (SNPs) modified with methyltrimethoxysilane (MTMS), which resulted in a significantly lower weight loss when compared to uncoated wood and other formulations. The nanocomposite coating was formed by the penetration of MTMS modified SNPs into surface voids and lumina of the wood, solidifying to form the nanocomposite film. The optimal ratio for commercialization was determined to be 40:60 SNPs:MTMS, and the improvement in abrasion resistance was due to both the suitable ratio and the physical and chemical interaction between the coating and wood.

3.2. Staining analysis results

The stain holding values of the samples were quite high. After 24 hours, water stain, soap stain, tea stain and acetone stain were not observed on the surface of the samples. But coffee stain slightly observed on surfaces (Figure 4). There is tannin in coffee. For this reason, it has a high ability to leave traces on the surfaces it is contaminated with. Coffee stains have a weak affinity for polyester, stronger adherence to cotton, and a notably strong interaction with nylon due to ionic bonding between coffee's carboxyl and phenolic groups and nylon's amine end-groups (Kissa, 1995).

Although the abrasion and scratching values of the protection varnish on the samples are low, it does not stain except for coffee stains. The harder the sample surfaces, the more resistant they were to stain (Zhong et al., 2013).

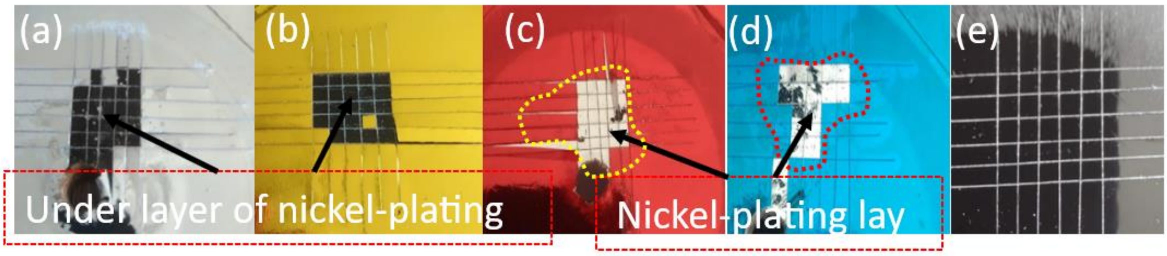


Figure 3. Nickel-plating samples cross-cut analysis results a) grey color, b) gold color, c) red color, d) blue color, e) black color

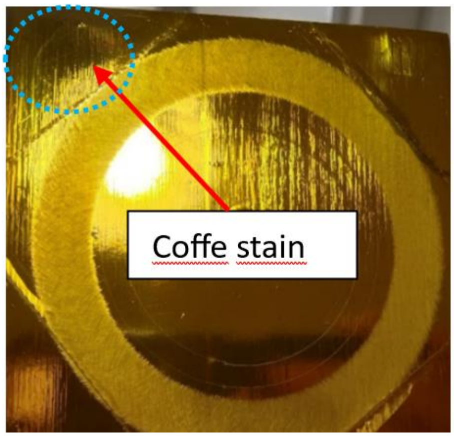


Figure 4. Coffee stain was slightly observed on all the sample’s surfaces

In some studies, to increase the stain resistance of wooden surfaces, superhydrophobic wood surface was created by immersing superhydrophilic wood in a solution containing perfluorooctyltriethoxysilane (PFOTS) and TiO_2 nanoparticles. The resulting coating repels water and other liquids with surface tensions in the range of 47 mN/m to 72 mN/m and exhibits durability against various tests such as water jet, abrasion, and tape peeling tests. The coated wood also demonstrates thermal and chemical stability, self-cleaning ability, and stain resistance, making it useful for both domestic and industrial applications (Gascón-Garrido et al., 2016). A recent study explored the use of atmospheric air plasma deposition to incorporate copper particles into wood micro-veneers, with the aim of enhancing the material's z-strength during artificial weathering. The findings showed that while the copper treatment did not offer protection against photo-degradation of lignin, it did provide photo-stabilization of wood polysaccharides, thereby improving the overall durability of the material. Additionally, the copper coating demonstrated antifungal properties and was effective in inhibiting fungal growth on the treated surface. The coating also offered resistance to blue stain, making it a promising solution for applications that require both durability and aesthetic appeal. Overall, the study highlights the potential of atmospheric air plasma deposition as a technique for modifying wood properties and enhancing its performance for various applications (Gascón-Garrido et al., 2016).

4. Conclusions

In this study, nickel-plating in 5 different (grey, black, blue, gold, red) colors was applied to the MDF, BP and PB surfaces. The surface strengths of the samples were determined by abrasion, scratch, and stain-resistance analyses. According to the abrasion results, the surface strength of the MDF samples was less than that of the BP and PB samples. Two scratch analyses were performed on the samples. Although the black color has the lowest scratch resistance according to the universal scratch tester analysis according to TS EN 15186 (2012), it was the highest in the cross-cut analysis according to TS EN ISO 2409 (2020). However, these two methods yielded contradictory results. It is thought that the black varnish used on the upper surface was soft and scratched quickly but did not separate from the surface. In the stain removal analysis results, no significant differences were detected among water, soap, tea, and acetone stains. Coffee stains were slightly evident on the surfaces of all samples. It was determined that the surface strength obtained with nickel plating is low and unsuitable for furniture use. Considering that nickel plating is more expensive than other types of plating, it is desirable to achieve better performance. But it does not meet this request.

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