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Improving Surface Quality of Resin Impregnated Paper Used for Laminated Flooring Overlaid

Poboljšanje kvalitete smolom impregniranog papira za pokrivni sloj laminata

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ABSTRACT • *This study aimed to improve the quality properties of impregnated papers used as a coating material in wood-based composites, especially for high-density fiberboard (HDF) floorings, using the Taguchi method and parameter design. Three factors were evaluated in determining the interactions as they are considered the most important in affecting the product quality characteristics such as particle size of Al_2O_3, surface modification agent and melamine raw material. Experiments were conducted in three replications using the L18 ($2^1 \times 3^2$) orthogonal array. Color and gloss measurements were evaluated together with the sensory analysis method, which takes into account the number of the spots in the sample as quality characteristics. The best values obtained as a result of statistical analysis were A_2 for the melamine raw material, 30 to 60 µm for the particle size and N-methyl-3-(trimethoxysilyl) propylamine for the surface modifier agent. Whether the experimental factors have a meaningful effect on the quality characteristics was also tested separately by analysis of variance. Only 58 % of the effect of the evaluated factors on the outcome could be expressed with the linear model (R^2_{adj} = 0.5785).*

KEYWORDS: *melamine-faced laminate, surface modification, experiment design, functional coating*

SAŽETAK • *Cilj ovog istraživanja bio je poboljšati kvalitetu impregniranih papira koji se upotrebljavaju kao pokrivni materijal za drvne kompozite, posebice za podove od tvrde ploče vlaknatice (HDF) primjenom Taguchijeve metode i projektiranja parametara. Za proučavanje interakcija odabrana su tri čimbenika za koja se smatra da najviše utječu na kvalitetu proizvoda. To su veličina čestica Al_2O_3, sredstvo za modifikaciju površine i melamin. Eksperimenti su provedeni na tri identična uzorka primjenom ortogonalnog niza L18 ($2^1 \times 3^2$). Rezultati boje i sjaja proučavani su zajedno metodom senzorske analize, koja kao odrednicu kvalitete uzima u obzir broj točaka na uzorku. Statistički najbolji rezultati dobiveni su za melamin A2, veličinu čestica 30 do 60 mm i za sredstvo za modifikaciju površine N-metil-3-(trimetoksilil) propilamin. Također, analizom varijance testirana je smislenost učinka eksperimentalnih čimbenika na kvalitetu papira. Samo 58 % evaluiranih čimbenika moglo se izraziti linearnim modelom (R^2_{adj} = 0,5785).*

KLJUČNE RIJEČI: *melaminom obložen laminat, modifikacija površine, projektiranje eksperimenta, funkcionalna prevlaka*

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1 INTRODUCTION
1. UVOD

The wood-based board (WBP) industry has shown a rapid upward trend since the beginning of the century. The industrial WBP production amount was 178 million tons in 2000 on a global scale and reached 387 million tons in 2015 (Morland and Schier, 2020). In China, the biggest industrial producer, plywood production increased from 826,900 m^3 to 171,952,300 m^3, fiberboard production increased from 1,481,000 m^3 to 62,970,000 m^3, and particleboard production increased from 483,100 m^3 to 2,777,700 m^3 in the period from 1988 to 2017 (Ke *et al.,* 2019). Similarly, Türkiye has become an important leader, rising to number one in Europe with 4.7 million m^3 of medium-density fiberboard (MDF) production (compound annual growth rate, CAGR, 12 %), and second with 92 million m^2 of laminate flooring production after Germany, which produced 227 million m^2 (İleri, 2020). In addition, it is also stated that to be consistent with the desired change towards a sustainable bio-economy, the consumption of the round wood should shift from its use as firewood or conventional paper to more efficient productions of wood-based panels or wood cellulose-based materials (Morland and Schier, 2020). Therefore, competition in existing markets is becoming increasingly aggressive as countries with rapid economic growth emerge as new competitors and significantly increase their pressure on the market (Kandelbauer *et al.,* 2010).

Around 70 % of the wood-based panels produced are covered with resin-impregnated paper sheets for decorative and protective purposes. As a result, it is inevitable for manufacturers of impregnated paper for WBP coating to produce innovative and quality products with less cost and higher productivity.

A typical laminate flooring product is composed of a high-density fiberboard (HDF) core, a balancing backing paper bonded underside of the core, a decorative paper that represents the wood grain on the top, and a wear-resistant overlay paper. The HDF core is produced using synthetic binders, mostly urea-formaldehyde, with lignocellulosic fibers. The main purpose of balancing backing paper is to provide strength to the core material and is generally made of low-grade papers. The decorative paper is composed of a thin layer of high-grade cellulose and represents the photographic illustration of the desired wood grain. A clear overlay paper carrying both the melamine resin and aluminum oxide particles (Al_2O_3, corundum) is on the top of the decor paper to provide the protection and stain resistance (Kim and Kim, 2006). Fine grounded particle-shaped aluminum oxide is spread onto the wet overlay paper during impregnation process. The durability of laminate flooring is determined by the AC (abrasion class) level. AC ratings are divided into five levels ranging from AC1 (moderate residential use) to AC6 (heavy commercial use).

In literature, parameters affecting the end product quality of the overlay paper production and melamine impregnation processes, such as resin type (urea-formaldehyde (UF), melamine-formaldehyde (MF), melamine-urea-formaldehyde (MUF), and phenol-formaldehyde (PF)), paper quality, and impregnation steps, have been extensively studied and their physical, chemical, and mechanical processes have been revealed in detail (Roberts and Evans, 2005; Nemli, 2008; Kandelbauer *et al.,* 2010; Thébault *et al.,* 2017). Most recent research has shown that the production of customer-specific products stands out. Researchers are now working for the discovery of innovative products that are more resistant to scratch, dirt, fungi, biological pests, and more considerate of the environment and human health while revealing ways to produce higher quality products at lower costs (Kim and Kim, 2006; Kandelbauer *et al.,* 2010; Badila *et al.,* 2014; Kohlmayr *et al.,* 2014; Nosál and Reinprecht, 2017). Thus, effective analysis processes are needed to produce quality products that can meet user demands, optimize the parameters affecting the process, and provide them on short notice. This study aimed to design the parameters to prevent heterogeneous color changes (blurring on the surface) that are especially visible on the surfaces of dark-colored HDF flooring products and white staining problem on the surface related to the size of the aluminum oxide particles. For this purpose, studies have been conducted to obtain laminate flooring products with improved quality properties by analyzing the effective parameters (melamine powder raw material, Al_2O_3 particle size, type of surface modifier agent) in overlay paper production and melamine resin impregnation with the Taguchi experimental design.

2 MATERIALS AND METHODS
2. MATERIJALI I METODE

2.1 Materials
2.1. Materijali

Raw overlay papers, melamine formaldehyde resins, and aluminum oxides (Al_2O_3) with different particle sizes used in the study were supplied by AGT Wood Industry and Trade Co. (Antalya, Türkiye). The general properties of the overlay paper are given in Table 1. N-methyl-3-(trimethoxy silyl) propylamine (MAMMO), 3-aminopropyl trimethoxysilane (AMMO) and 3-glycidyloxypropyl trimethoxysilane (GLYMO) were obtained from Merck. Hydrochloric acid and ethyl acetoacetate were obtained from Sigma-Aldrich. Melamine types belonging to two different companies (A1 and A2) were used in the MF resin synthesis.

Table 1 Properties of overlay paper
Tablica 1. Svojstva pokrivnog papira

Grammage / *Gramaža*	g/m²	25 ± 2.0
Wet tensile strength *Vlažna vlačna čvrstoća*	N/15 mm	> 5.5
Porosity / *Poroznost*	1/m²s	> 100
Capillary rise *Kapilarna upojnost*	mm/10 min	< 70
pH value / *pH-vrijednost*		6.2 ± 0.5

2.2 Preparation of resin impregnated paper
2.2. Priprema papira impregniranoga smolom

The pre-hydrolysis process, which is the same with N-methyl-3-(trimethoxy silyl) propylamine (MAMMO), is exemplified by the use of 3-aminopropyl trimethoxysilane (AMMO). A total of 20 g (0.1 mol) of AMMO was weighed into a container and to perform the pre-hydrolysis reaction of the ethoxy groups (0.3 mol), sufficient amounts of 2.7 g (0.15 mol) distilled water and 0.5 g 1 M HCl were added. The prepared solution was left to stir at room temperature for 2 h.

In the pre-hydrolysis of the systems prepared by using 3-glycidyloxypropyl trimethoxysilane (GLYMO), aluminum ethyl acetoacetate (Al(1:1) HacacOEt) (%30 by mole) was also used with hydrochloric acid to catalyze and open the epoxy ring. The prepared solution was stirred at room temperature for 4 h.

It is important to note that the alumina particles need to be pre-treated so that they will be more compatible with the MF resin, thus providing higher bonding and strength. In this regard, the above mentioned silane compounds were chosen because of their low cost, availability and ease of use in the hydrolization process.

With the preparation of the modifier solutions, the surface modification phase of the Al_2O_3 particles was conducted. Corundum samples with different particle sizes (30 to 60 µm, 60 to 80 µm, and 80 to 125 µm) were weighed into separate containers as 9 g each and homogeneously mixed with the modifier silane solutions. The modifier ratio was taken as 3 wt% in all systems to observe the effect of silane compounds with different functional groups. Surface-modified corundum systems were pre-dried in an oven at 70 °C for 1 h, adjusted for moisture content and stored until used.

The corundum amount on the surfaces of the AC4 group (≥ 4000 revolutions according to Taber abraser, EN 438-2) laminate flooring products used in the studies should be at least 22 g/m² according to the standard TS EN 13329 A1 (2017). According to this scale, the amount of Al_2O_3 to be used on 40 cm x 40 cm overlay paper was determined as 3.68 g. Selge model decor paper and Timberland model (HUECK, Lüdenscheid, Germany) press sheet were used in all studies. Decor papers are impregnated with 60 g of two different melamine (A_1 and A_2) formaldehyde resins. Al_2O_3 particles were homogeneously dispersed on impregnated overlay paper by using a series of 40 to 63 to 75 µm sieves for 30 to 60 µm-sized particles, 63 to 75 µm sieves for 60 to 80 µm-sized particles, and 75 to 90 to 106 to 125 µm sieves for 80 to 125 µm-sized particles.

Overlay papers carrying the corundum particles were combined with decor papers, placed on HDF panels and pressed for 35 s at 220 N/m² pressure and 185 °C press (ImalPal PL100, Imal Group, Modena, Italy) temperature. A total of 18 × 3 sample panels were prepared in accordance with the experimental design. In the preparation phase of the samples, it was important to focus on randomizing to ensure the homogeneous distribution of the possible effects of the uncontrollable factors across all samples that may affect the test results. The samples coded with random numbers, created in accordance with the uniform distribution of the Excel RAND function (Microsoft Excel, Microsoft Corporation, Version 2013, Redmond, WA, USA), were produced by considering this order.

2.3 Experimental design
2.3. Postavke eksperimenta

Taguchi experimental design is an experimental design method that tries to minimize the uncontrollable factors that create the variability in the product and process by choosing the most appropriate combination of controllable factor levels with performing fewer experiments than the traditional experimental design (Taguchi *et al.,* 2005). It is a direct replacement of traditional One-Factor-At-A-Time or the 'Hit or Miss' approach to experimentation (Antony, 2003).

The goal of the experimental design is to find a link between various variables and an objective characteristic (response). It is critical to identify the proper connection (model) accurately and effectively while designing experiments. These words must be included when there are substantial interactions between variables (causes). The signal to noise ratio (*S*/*N*), a measure of functionality, is introduced through parameter design, and orthogonal arrays are used to test the importance of interactions between control elements. If these interactions are substantial, the repeatability of conclusions is disputable. The *S*/*N* ratios indicate how a control factor, a signal factor (*S*), and noise factors (*N*) interact. The use of the *S*/*N* ratio allows for the avoidance of control factor interactions. However, as it is unknown whether or not the interactions between control factors are noticeable simply by adding the *S*/*N* ratio, orthogonal arrays are employed to screen for significant interactions (Taguchi *et al.,* 2005).

In the study, the quality performance characteristic is considered as the production of a HDF laminate flooring product that minimizes the formation of white spots on its surfaces. The production methods in the factory were observed to determine the factors and in-

Table 2 Experimental Factors and Levels
Tablica 2. Čimbenici i razine eksperimenta

Factors / *Čimbenici*	**Levels** / *Razine*		
	1	2	3
Melamine powder, raw material / *melaminski prah, sirovina*	A_1	A_2	-
Particle size of Al_2O_3 / *veličina čestica* Al_2O_3	30 to 60 µm	60 to 80 µm	80 to 125 µm
Surface modification agent *sredstvo za modifikaciju površine*	3-aminopropyl trimethoxysilane	3-glycidyloxy-propyl trimethox-ysilane	N-methyl-3-(trimethoxysilyl) propylamine

teractions and three factors affecting the quality characteristics that were selected within the study framework (Table 2).

The L18 ($2^1 \times 3^2$) orthogonal index for factors and levels was selected and necessary analyses were performed using Minitab software (Version 16, Minitab Inc., State College, PA, USA). The selected array indicated that 18 experiments should be performed. Each experiment was repeated three times to reduce variation. Thus, measurements were made on 18 × 3 = 54 samples. L18 arrays are highly recommended because the interactions are distributed uniformly to all columns (Taguchi *et al.,* 2005; Nas and Altan Ozbek, 2019).

2.4 Color and gloss measurements
2.4. Mjerenje boje i sjaja

The purpose of the color measurements is not to make precise color definitions on laminate flooring surfaces, but to calculate the total color difference (metric) (ΔE^*) occurring in the samples compared to the control group using the CIE Lab 1976 (Commission Internationale d'Eclairage) standard (Sahin and Mantanis, 2011). ΔE is defined as the difference between two colors in an $L^*a^*b^*$ color space. ΔE^* is total color difference and is calculated based on delta L^*, a^*, b^* color differences (Eq.1):

$$\Delta E^* = \sqrt{\left(\Delta L^*\right)^2 + \left(\Delta a^*\right)^2 + \left(\Delta b^*\right)^2} \qquad (1)$$

Ten measurements were made on each specimen and the average of the color values were obtained. All color measurements were made with a portable X-Rite SP 968 spectrophotometer (X-Rite Inc., Grandville, MI, USA), which automatically calculated. A D65 illuminant and a 10-degree standard observer were used to make the measurements.

In the study, surface gloss measurements were made with a Pacific Scientific Glossgard II 60° gloss meter according to ASTM D523-14 (2018) standard. Measurements were repeated ten times and the average values were calculated to evaluate the color and gloss of each sample.

2.5 Sensory analysis method
2.5. Metoda senzorske analize

Visual control was carried out by the sensory analysis method to determine the intensity of white

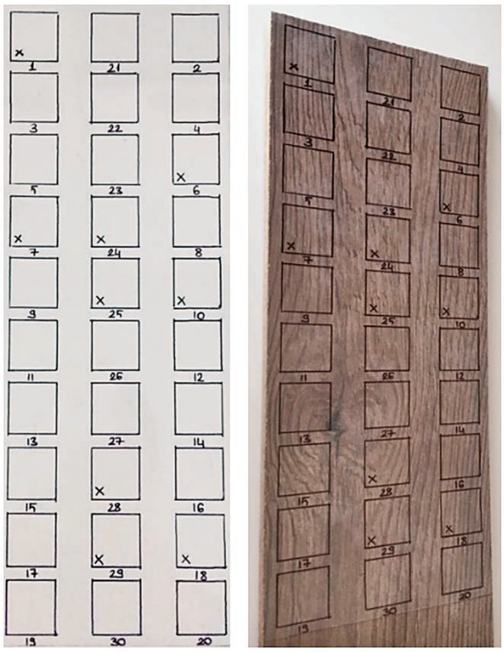

Figure 1 Template used to determine stain density
Slika 1. Predložak za određivanje intenziteta obojenja

staining on laminate flooring surfaces. A template with a 10 cm × 30 cm size was prepared for this purpose. Then, 30 cells of 4 cm^2 area were created in the template and then 10 of them were randomly selected (Figure 1). The number of cells with the staining on this template was noted and evaluated on a scale of 1 to 10.

3 RESULTS AND DISCUSSION
3. REZULTATI I RASPRAVA

3.1 Experimental results
3.1. Eksperimentalni rezultati

The effect on the three quality characteristics (stain, color, and gloss) was evaluated separately and tested by analysis of variance (ANOVA) to determine whether the experimental factors had a significant effect on the stated quality characteristics.

It was observed in analyses made for the stain quality characteristics that all factors and interactions had a significant effect on the results at the 95 % confidence level, except for the Factor_1*Factor_3 (M*A) interaction ($P < 0.05$) (Table 3).

Table 3 ANOVA results for color, gloss, and stain count
Tablica 3. ANNOVA rezultati za boju, sjaj i intenzitet obojenja

Variance source *Izvor varijance*	**Degree of freedom (*DoF*)** *Stupanj slobode (DoF)*	**Sum of squares (*SS*)** *Zbroj kvadrata (SS)*	**Mean squares (*MS*)** *Srednji kvadrati (MS)*	***F* value** *F-vrijednost*	***P* value** *P-vrijednost*	**Contribution rate** *Doprinos*
Color (Δ*E*)						
M	1	0.0413	0.04133	0.05	0.825	11.14 %
P	2	4.7107	2.35533	2.82	0.073	2.72 %
A	2	3.3318	1.66590	2.00	0.150	5.94 %
M*P	2	5.4046	2.70231	3.24	0.051	35.44 %
M*A	2	0.1846	0.09230	0.11	0.896	0.31 %
P*A	4	3.7055	0.92639	1.11	0.366	6.21 %
M*P*A	4	1.2694	0.31735	0.38	0.821	1.55 %
Error	36	30.0172	0.83381			36.69 %
Total	53	81.8075				100 %
	R^2	R^2_{adj}				
	63.31%	45.98%				
Gloss Unit (*GU*)						
M	1	9.728	9.7283	17.37	0.000	17.50 %
P	2	9.935	4.9674	8.87	0.001	3.91 %
A	2	12.369	6.1844	11.04	0.000	16.29 %
M*P	2	8.372	4.1858	7.47	0.002	0.71 %
M*A	2	7.737	3.8686	6.91	0.003	3.46 %
P*A	4	17.845	4.4613	7.96	0.000	7.68 %
M*P*A	4	12.789	3.1972	5.71	0.001	15.69 %
Error	36	20.168	0.5602			24.75 %
Total	53	81.492				100 %
	R^2	R^2_{adj}				
	75.25%	63.57%				
Stain Count (*SC*)						
M	1	10.667	10.667	5.14	0.029	16.36 %
P	2	22.889	11.444	5.52	0.008	14.58 %
A	2	13.556	6.778	3.27	0.050	13.65 %
M*P	2	18.778	9.389	4.53	0.018	0.55 %
M*A	2	4.333	2.167	1.04	0.362	3.88 %
P*A	4	57.259	14.315	6.90	0.000	11.45 %
M*P*A	4	28.444	7.111	3.43	0.018	10.91 %
Error	36	74.667	2.074			28.63 %
Total	53	260.815				100 %
	R^2	R^2_{adj}				
	71.37%	57.85%				

M – Melamine powder raw material, P – Al_2O_3 particle size, A – Surface modification agent / *M – melaminski prah, sirovina, P – veličina čestica* Al_2O_3, *A – sredstvo za modifikaciju površine*

The detailed analysis conducted for the Stain Count quality characteristic was also performed for the color values, but it was observed that the factors and their interactions did not have a significant effect ($P > 0.05$) (Table 3).

In the analysis made for the Gloss quality characteristic, it was determined that the factors and their interactions had a significant effect at the 95 % confidence level (Table 3). However, this high interaction occurs naturally due to low gloss (high opacity) in stained areas and high gloss in unstained areas. This situation, which cannot be avoided during random measurements, makes it impossible to monitor the effect of the test condition. For this reason, although all response values were included in the Taguchi analysis, in the calculation of *S*/*N* ratios and in drawing the graphs, detailed analyses were made only for the "Stain Count" quality characteristic considering that the significant relationship may be misleading.

The *S*/*N* ratio of the Taguchi method has three quality characteristics as nominal-the-best, smaller-the-better, and larger-the-better (Taguchi *et al.,* 2005). In this study, the characteristics defined were smaller-the-better for the Δ*E* and the Stain Count and larger-the-better for the Gloss. Table 4 shows the *S*/*N* ratios and the experimental Color (Δ*E**), the Gloss Unit (*GU*), and the Stain Count (*SC*) results obtained *via* the Taguchi L18 experimental design.

Table 4 Experimental results and *S/N* ratios
Tablica 4. Eksperimentalni rezultati i *S/N* omjeri

	Control factors *Kontrolni čimbenici*								
Exp. No	M	P	A	Color (ΔE)	Gloss (*GU*)	Stain (*SC*)	*S/N* for Color	*S/N* for Gloss	*S/N* for Stain
1	A_1	30 to 60 µm	AMMO	1.876	13.25	5	-6.2905	23.4577	-12.9373
2	A_1	30 to 60µm	GYLMO	3.547	16.81	3	-9.3477	24.7145	-8.6530
3	A_1	30 to 60µm	MAMMO	3.348	18.00	2	-11.0398	25.0109	-3.0103
4	A_1	60 to 80µm	AMMO	3.894	11.45	10	-11.8801	22.5667	-17.6343
5	A_1	60 to 80 µm	GYLMO	3.802	16.98	3	-14.0874	24.4287	-10.5436
6	A_1	60 to 80 µm	MAMMO	6.197	17.45	2	-14.2477	24.8838	-6.0206
7	A_1	80 to 125 µm	AMMO	2.743	16.04	3	-9.3087	24.2591	-12.1307
8	A_1	80 to 125 µm	GYLMO	2.100	13.56	10	-8.0339	23.3820	-18.5733
9	A_1	80 to 125 µm	MAMMO	2.608	16.12	3	-7.6843	24.4757	-11.5635
10	A_2	30 to 60 µm	AMMO	1.611	17.88	2	-5.5969	24.9217	-4.7712
11	A_2	30 to 60 µm	GYLMO	2.186	17.34	1	-7.3454	24.8520	-4.7712
12	A_2	30 to 60 µm	MAMMO	3.160	17.35	0	-11.8520	24.7366	-4.7712
13	A_2	60 to 80 µm	AMMO	1.825	17.28	2	-4.5161	24.8022	-6.0206
14	A_2	60 to 80 µm	GYLMO	1.477	16.92	3	-5.7872	24.5930	-8.6530
15	A_2	60 to 80 µm	MAMMO	1.733	17.52	0	-5.2552	24.8006	-6.3682
16	A_2	80 to 125 µm	AMMO	2.368	17.11	4	-10.3494	24.4199	-10.7918
17	A_2	80 to 125 µm	GYLMO	2.401	17.04	6	-9.9562	24.6681	-12.5527
18	A_2	80 to 125 µm	MAMMO	3.561	17.13	2	-10.8483	24.8045	-7.5333

M – Melamine powder raw material, P – Al_2O_3 particle size, A – Surface modification agent (AMMO: 3-aminopropyl trimethoxysilane, MAMMO: N-methyl-3-(trimethoxylyl) propylamine and GLYMO: 3-glycidyloxypropyl trimethoxysilane) / *M – melaminski prah, sirovina, P – veličina čestica Al_2O_3, A – sredstvo za modifikaciju površine (AMMO: 3-aminopropil trimetoksilan, MAMMO: N-metil-3-(trimetoksilil) propilamin i GLYMO: 3-glicidiloksipropil trimetoksilan)*

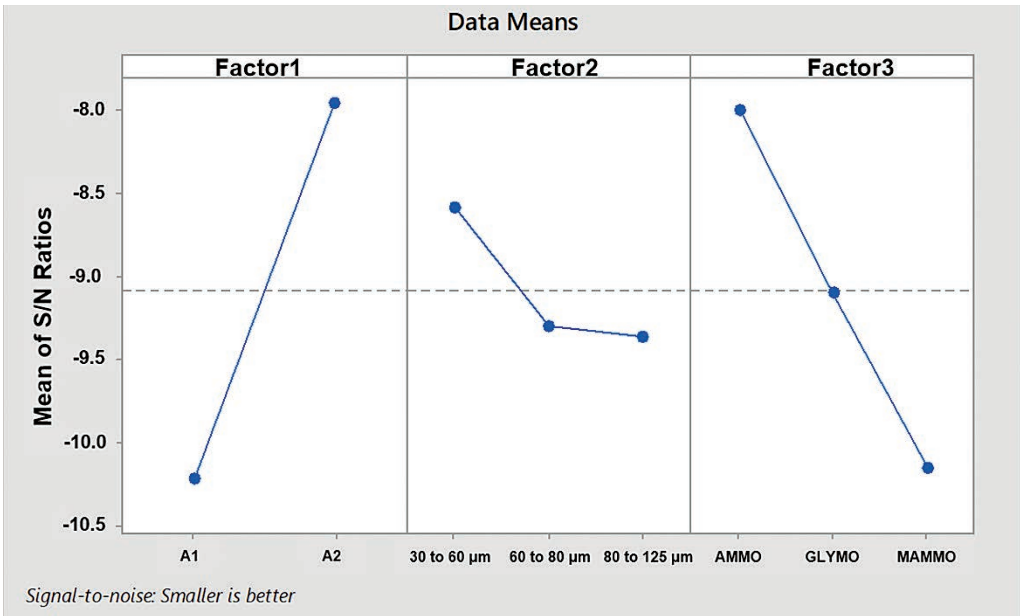

Figure 2 Process parameter effects on *S/N* ratio for color
Slika 2. Utjecaji procesnih parametara na *S/N* omjer za boju

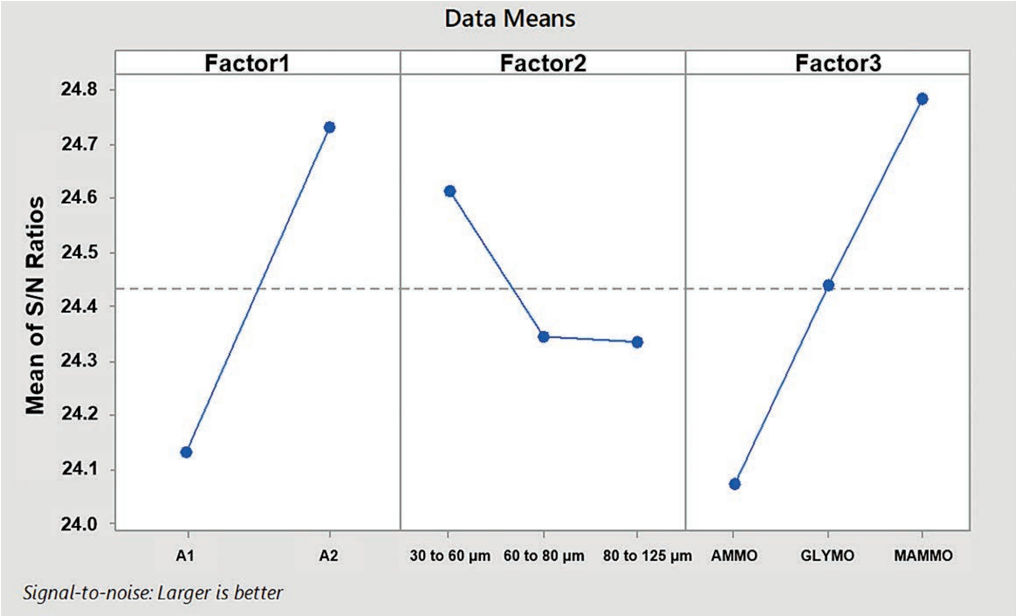

Figure 3 Process parameter effects on *S/N* ratio for stain
Slika 3. Utjecaji procesnih parametara na *S/N* omjer za obojenje

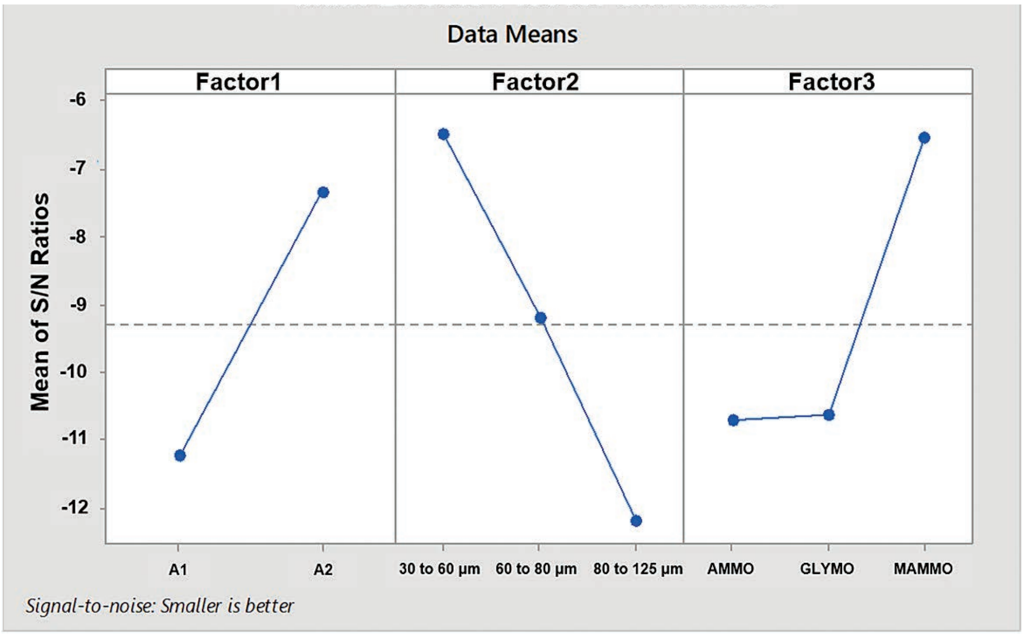

Figure 4 Process parameter effects on *S/N* ratio for stain
Slika 4. Utjecaji procesnih parametara na *S/N* omjer za obojenje

As a result of the analyses and the evaluation of the graphics, it was observed that the most suitable combination was obtained by using the A_2 melamine powder raw material, the Al_2O_3 with a particle size of 30 to 60 µm and the surface modification agent of N-methyl-3-(trimethoxy silyl) propyl amine (Figure 4).

Confirmation tests were performed for the determined combination. The mean values of the analyses (0.156) and the confirmation tests (0.666) showed the compatibility of each other.

3.2 SEM Results
3.2. Rezultati SEM-a

Laminate flooring samples produced in accordance with the result of the most suitable combination were cut in 2 cm × 2 cm dimensions, analyzed with a scanning electron microscope (SEM-FEI Quanta FEG 250) and SEM images were taken.

Taguchi analysis revealed that the best combination was A_2 / 30 to 60 µm / N-methyl-3-(trimethoxy silyl) propyl amine, while the worst combination was

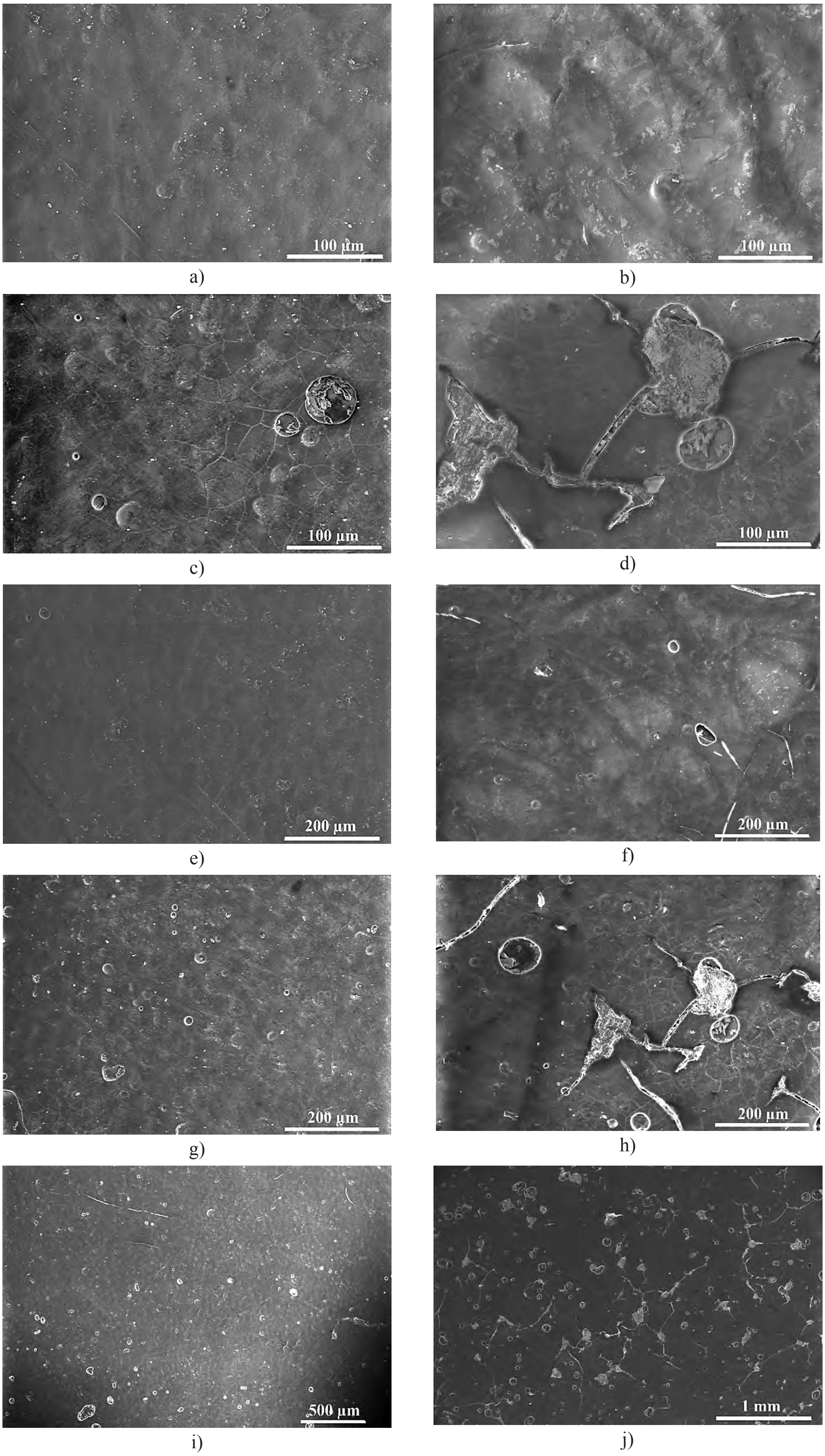

Figure 5 SEM images of: 1- best combination: a: 100 µm, c: 100 µm, e: 200 µm, g: 200 µm, i: 500 µm, and 2- worst combination: b: 100 µm, d: 100 µm, f: 200 µm, h: 200 µm, j: 1 mm)
Slika 5. SEM fotografije: 1 – najbolja kombinacija (a: 100 mm, c: 100 mm, e: 200 mm, g: 200 mm, i: 55 mm), 2 – najlošija kombinacija (b: 100 mm, d: 100 mm, f: 200 mm, h: 200 mm, j: 1 mm)

A_1 / 80 to 125 µm / 3-aminopropyl trimethoxysilane. In Figure 5, the images of the same magnification were compared according to the combinations. The combination of A_2 / 30 to 60 µm / N-methyl-3-(trimethoxysilyl) propyl amine, which had almost no white spots by sensory analysis, appeared to be homogeneously distributed when microscopic images were examined. In the microscopic images of the combination of A_1 / 80 to 125 µm / 3 to aminopropyl trimethoxysilane, which had intense white staining on the surface, there was no homogeneity, and cluster formations were observed. It was found that these clusters in the SEM images and the white staining that occur on the laminate surfaces overlap with each other (Figure 5).

4 CONCLUSIONS
4. ZAKLJUČAK

While no significant relationship was found for the color quality characteristic, the gloss characteristic provided a meaningful result. It was determined that the gloss was low in the areas with staining on the samples, while it was high in the areas where there were no spots.

In this study, the data belonging to the stain variable are qualitative data determined by sensory analysis. Qualitative data can also be obtained by using image processing techniques in future studies.

Only 57 % of the effects of the evaluated factors on the result (staining) could be expressed in the linear model (R^2_{adj} = 0.5785). The effect of other factors that were not evaluated by the model was also too high to be ignored. However, due to the working conditions and limitations, the study was completed with the existing evaluation factors.

The best values obtained by statistical analysis were estimated to be A_2 for the melamine raw material, 30 to 60 µm for the particle size, and N-methyl-3-(trimethoxysilyl) propyl amine for the surface modifier agent. The validation test result showed that the analysis result was consistent with the average of 0.156.

In addition, SEM images of the samples with different combinations predicted as the best and the worst by Taguchi analysis were compared. It was found that these clusters in the SEM images and the white staining that occur on the laminate surfaces overlap with each other.

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