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Effects of Crosslinker and Silicon to Enhance Taber Abrasion and Physical Properties of Finished Leather for Upholstery Furniture

Atiqa Rahmawati, Elis Nurbalia*, Rini Tiyastuti

Department of Leather Processing Technology, Politeknik ATK Yogyakarta, Yogyakarta, Indonesia, 55188

*Corresponding Author: elisnurbalia@atk.ac.id

Abstract

Finishing is one of the stages in leather processing. The addition of silicone and crosslinker in the top coat of the finishing stage of leather upholstery furniture is used to increase abrasion resistance, which is a critical factor in determining the life and quality of leather furniture. The aim of this study was to determine the influence of silicone and crosslinker additions on the abrasion resistance and physical properties of leather upholstery furniture. The leather material used is dyed crust leather grade C50 (leather without defects) with a thickness of 1.2-1.4 mm and an area of 1.5 sqft. The addition of crosslinker and silicone is applied only to the top coat. The analyses performed including physical properties evaluation (adhesion test ISO 11644 2009, rubbing fastness ISO 11640, glossy test, and flexing ISO 5402-1:2017) and organoleptic evaluation (Taber abrasion and smoothness tests). The addition of crosslinker and silicone can affect the physical properties and organoleptic quality of leather. The addition of crosslinker and silicone to the top coat showed the best results on upholstery leather sample D (3% crosslinker and 4% silicone). The results of statistical tests using the multinomial logistic regression method in organoleptic testing and ANOVA in physical testing showed that only crosslinker had a significant effect on the response.

Keywords: crosslinker, leather, silicon, upholstery

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Finishing merupakan salah satu tahapan dalam pengolahan kulit. Penambahan silikon dan crosslinker pada lapisan top coat pada artikel kulit upholstery furniture dapat meningkatkan ketahanan abrasi yang merupakan faktor penting dalam menentukan umur dan kualitas furnitur kulit. Tujuan dari penelitian ini adalah untuk mengetahui pengaruh penambahan silikon dan crosslinker terhadap ketahanan abrasi dan sifat fisik kulit upholstery furniture. Material kulit yang digunakan adalah kulit *dyed crust* grade C50 (tidak ada defek) dengan ketebalan 1,2-1,4 mm dan luas 1,5 sqft. Penambahan crosslinker dan silikon hanya diaplikasikan pada top coat. Analisis yang dilakukan meliputi analisis fisik kulit (adhesion test ISO 11644 2009, rubbing fastness ISO 11640, glossy test, and flexing ISO 5402-1:2017) dan uji organoleptik (uji ketahanan abrasi dan kelicinan). Penambahan crosslinker dan silikon dapat mempengaruhi kualitas kulit baik secara fisik dan organoleptik. Penambahan crosslinker dan silikon pada top coat menunjukkan hasil terbaik pada sampel kulit D dengan penambahan 3% crosslinker dan 4% silikon. Hasil uji statistik menggunakan metode regresi logistik multinomial pada pengujian organoleptik dan ANOVA pada pengujian fisik menunjukkan hanya crosslinker yang berpengaruh nyata terhadap respon, sedangkan silikon tidak berpengaruh secara signifikan terhadap respon.

Kata Kunci: crosslinker, leather, silikon, upholstery

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INTRODUCTION

Industrial growth in Indonesia is very rapid that it has an important role in the development of the nation's economy. One industry that is found has economic impact is leather industry. Animal skins are often used for making jackets, shoes, wallets, bags, and decorations [1]. One of the products that can be made from leather is upholstery articles. Upholstery for sofas or upholstery furniture usually uses fabric [2] leather [3] dan synthetic leather. Upholstery leather made from cowhide through various processes, such Beamhouse Operation (BHO), tanning, post-tanning, and finishing. Finishing is the final part in leather processing. This process determines the appearance and value of the final product. The purpose of finishing is to provide an attractive appearance, pleasant feel, cover defects, and provide a layer that protects the leather surface, and increasing the leather's resistance to external factors [4].

The finishing process on upholstery furniture has three important layers. The layers are base coat, medium coat, and top coat [5]. The function of base coat layer is providing adhesion properties between the leather and the coating, medium coat serves as a color carrier layer that is responsible for the rubbing resistance of the leather, top coat is the top layer that assists to protect leather from friction, scratches, dust, and others [6]. According to Purnomo [7] top coat layer significantly affects the surface and wear resistance, such as abrasion resistance, scuffing/friction, wet and dry crock properties. Furniture upholstery leather must have high wear resistance; it is due to daily use that cause potential for friction in the leather. The addition of silicone and crosslinker in the top coat of upholstery furniture leather is used to improve abrasion resistance, which is a critical factor in determining the life and quality of leather furniture. Silicone, with its hydrophobic properties and ability to form a protective layer, can increase the surface resistance to friction. This characteristic allows the leather surface to be more resistant to scratches and damage from daily use, thus maintaining the appearance of durable furniture for a longer period of time.

The aim of this study is to determine the effect of the silicone and crosslinker addition for abrasion resistance and physical properties of furniture upholstery leather. By improving abrasion resistance, it is expected to extend product life and reduce maintenance costs. This study considers the effect of the addition of crosslinker and silicone on the Taber abrasion (abrasion resistance), slipperiness, and explains the effect of the addition of crosslinker and silicone on physical properties (rubber fastness, adhesion, and glossy test).

MATERIALS AND METHODS

Materials

Dyed crust leather with a thickness of 1.2- 1.4 mm in 5 pieces with an area of 1.5 sqft for each piece. Distilled water, biocide, polyacrylic, wax and matt agent, aliphatic polyurethane, PU medium, emulsifier, silicone, crosslinker, pigment was used. The tools and machines used are staking machine, milling machine, embossing roller, spray gun, toggling machine, Flexo meter, Taber abrasion test, rubbing machine test, Universal tensile machine, digital thickness, glossmeter.

Finishing leather with crosslinker and silicon addition

Leather preparation: Dyed crust leather is graded according to C50 (leather without defects). The leather that has been sorted and graded is then staked, and roller embossed to emboss the leather grain. Finishing is done through three stages: base coat, medium coat and top coat. The formulation for the base coat and medium coat in samples A, B, C, D were uniformed, while the top coat layer varied the addition of crosslinker and silicon. The finishing formulation can be seen in **Table 1.**

Physical properties evaluation

Adhesion test based on ISO 11644 2009. Flexing test was performed using a Flexo meter based on ISO 5402-1:2017, in the sample used, the flexing test was set at 50,000 cycles. Rubbing fastness was conducted based on ISO 11640. Rubbing fastness testing was carried out for samples with sweat, wet and dry treatments. For sweat was used 80 cycles, wet for 250 cycles, and dry for 500 cycles. The results were observed and adjusted to the grayscale standard. Glossy test is conducted based on the company's standard, the sample is placed on a flat panel then the glossmeter is placed on the skin and pressed until the value appears on the glossmeter. The glossy value is in the range of 1.8-2.2 U.G

Leather slipperiness

Leather slipperiness testing is carried out by expertise with standards from the customer. Sample were placing on the flat board, then felt to determine the level of slipperiness of the leather. Result of the slipperiness test are compared with the control grading of the slipperiness test. The testers were 20 people from the finishing department.

Taber abrasion (abrasion resistant)

Preparing a test specimen, scraping the surface of the skin for 1200 cycles. Then the test results were observed by the expert by looking at the friction marks between the skin and the magnifying glass. Grading on each test sample is adjusted to the test standard as in **Table 2**. The test respondents were 20 people from the finishing department.

Analysis data

Statistical analysis of multinomial logistic regression was used to analyze of Taber abrasion and slipperiness. Logistic multinomial regression is one of the statistical methods used to find the relationship of the dependent variable in the form of multinomial qualitative data (more than two categories) with one or more independent variables [8]. While the ANOVA test was used to analyze the adhesion test. The confidence level value used is 95% (α =0.05).

Table 1. Upholstery Furniture Leather Finishing Formulation

Parameters	Formulation			
	Sample A	Sample B	Sample C	Sample D
Base coat:				
Air (gr)	245	245	245	245
Biocide (gr)	0.8	0.8	0.8	0.8
Polyacrylic (gr)	483.40	483.40	483.40	483.40
Wax and matt agent (gr)	42.0	42.0	42.0	42.0
PU (soft) (gr)	108.7	108.7	108.7	108.7
Wax (gr)	120.0	120.0	120.0	120.0
Pigment (gr)	100	100	100	100
Medium coat:				
Air (gr)	316.0	316.0	316.0	316.0
Polyacrylic (gr)	200.3	200.3	200.3	200.3
Wax and matt agent (gr)	70.0	70.0	70.0	70.0
Wax (gr)	160.0	160.0	160.0	160.0
Medium PU (gr)	54.5	54.5	54.5	54.5
PU (gr)	200.0	200.0	200.0	200.0
Pigment (gr)	150.0	150.0	150.0	150.0
Top coat:				
Air (gr)	365	365	365	365
PU (gr)	607.0	607.0	607.0	607.0
Emulsifier (gr)	12.0	12.0	12.0	12.0
Silicon (gr)	30 (3%)	40 (4%)	30 (3%)	40 (4%)
Crosslinker (gr)	20 (2%)	20 (2%)	30 (3%)	30 (3%)

Table 2. Taber abrasion and slipperiness grade

Grade	Taber Abrasion	Slipperiness
1	Crust appearances of 0.5mm	There are changes on the slipperiness level
2	Crust appearances max 0.5mm	There are changes on the slipperiness level
3	Peeling a lot, breadth and depth	Slipperiness level less than grade 2
4	Peeling less than grade 3	Slipperiness level less than grade 3
5	No Peeling	No change in slipperiness

RESULTS AND DISCUSSION

Effect of silicone and crosslinker on Taber abrasion and slipperiness

The results of Taber abrasion and slipperiness analysis can be seen in **Table 3**. Taber abrasion testing is conducted to ascertain the surface durability of a material. Taber abrasion is performed on leather to evaluate its resistance to wear, which is presumed to correlate with the material's wearability [9]. In **Table 3**, it is discernible that when using a 2% crosslinker, the mean value of Taber abrasion showed a reduction with the incorporation of 3% and 4% silicon. Conversely, with 3% crosslinker was utilized, the Taber abrasion has enhanced with the addition of 3% and 4%, specifically increasing from 3.75 to 4.5 (on a scale of 5).

The increase in the Taber abrasion value can be ascribed to the function of the integrated crosslinker, which promotes the formation of crosslinks with polyurethane, consequently to the development of a durable layer that is waterproof and has abrasion-resistant ability to protect the skin [10]. Furthermore, the use of crosslinkers that bind to polyurethane binder's results in a finish leather that has resistance to oil, fat, and organic solvents, thereby improving the mechanical properties of the coating such as hardness, toughness, and Taber abrasion [11]. According to Ramkumar *et al.* [11] during the final phase of finishing, isocyanates, recognized as crosslinking agents, are frequently used, due to their reactions with alcohols, amines, and acids that make a hard film layer via crosslinking, thus enhancing the resistance to abrasion of the finishing layer. The addition of silicone within the top coat shows a crucial role in shaping both the comfort and visual appeal of the final leather product. Furthermore, silicone also contributes to enhanced resistance against wear, water resistance and smooth surface that improved leather quality [12,13]. The combination of silicon and crosslinker additions that get the best abrasion and slipperiness Taber values is at 4% silicon and 3% crosslinker. The combination of silicon and crosslinker formula that produces the optimal Taber abrasion and slipperiness is determined to be 4% silicon and 3% crosslinker.

Table 3. Result of Taber abrasion and slipperiness

Test Sample	Variable Silicon	Cross linker	Mean Taber Abrasion	Mean Slippe-riness
Sample A	3%	2%	3.5	4.75
Sample B	4%	2%	3.25	5
Sample C	3%	3%	3.75	4.25
Sample D	4%	3%	4.5	4.25

The statistical results obtained from the multinomial logistic regression (refer to **Table 4**) indicate that the Taber abrasion response within the established model exhibits a p-value of 0.188 (>0.05), thus indicating that the variables of silicone and crosslinker do not have an impact on the dependent variable (Taber abrasion). This statement is further substantiated by the results of the partial tests, which present a p-value of 0.719 for silicone and 0.059 for crosslinker; both values exceed α (α=0.05), indicating that neither variable has a statistically significant impact on the dependent variable. The pseudo-R-square value is 0.364 (36.4%) which means the relationship of Taber abrasion variability that can be explained by silicon and crosslinker is 36.4% and the remaining 63.6% is explained by other factors (cannot be explained by the model). So, it can be concluded that the variation of silicon and crosslinker variables has no significant effect on the Taber abrasion value.

The statistical results obtained on the slipperiness response have a model fitting p-value of 0.026 (<0.05), which means that there are variables that have a significant effect on the slipperiness. This is shown by the results of partial testing with a silicone p-value of 0.513 (>0.05) and a crosslinker p-value of 0.008 (<0.05), this means that the crosslinker variable has a significant effect on the slipperiness value. The pseudo-R-square value 0.493 (49.3%) which means that the variability relationship of slipperiness can be explained by silicon and crosslinker is 49.3% and the remaining 50.7% is explained by other factors (cannot be explained by the model). Thus, one can conclude that the variations in silicon parameters do not affect the response, while the crosslinker has an effect on slipperiness.

Table 4. Statistical analysis of multinomial logistic regression of Taber abrasion and slipperiness

	Taber abrasion	slipperiness
Model fitting		
- Chi-square	6.148	7.332
- Sig.	0.188	0.026
Goodness-of-Fit		
Pearson sig.	0.259	0.367
Pseudo R-square	0.364	0.493
Likelihood Ratio Tests		
Silicon		
- Chi-square	0.661	0.428
- Sig.	0.719	0.513
Crosslinker		
- Chi-square	5.665	7.078
- Sig.	0.059	0.008

Effect of silicone and crosslinker to the physical properties of leather

The results of the physical properties of leather can be seen in **Table 5**. **Table 5** shows the results of the physical properties of leather with adhesion resistance test, rubbing fastness, and glossy test. **Figure 1** shows the results of the physical analysis of samples A, B, C, and D to the physical properties of leather. Of the four samples, sample D has the best physical quality, with the highest grayscale standard from rubbing fastness analysis (sweat, wet, and dry); highest adhesion test; and highest glossy test. The effect of silicone and crosslinker to the physical properties of leather explain in **Figure 1**.

Adhesion test

Adhesion testing is conducted to evaluate the durability of the leather finishing layer when subjected to a specific tensile force. Adhesion resistance serves as a metric for assessing the toughness of the finishing layer in relation to the substrate (leather) [14]. The adhesion test results are presented in **Table 5**. Sample A showed an adhesion strength of 4.83 N, Sample B 4.49 N, Sample C 6.04 N, and Sample D 6.34 N. All samples fulfilled the predetermined customer adhesion standard. Enhanced adhesion values indicate that

Table 5. Result of physical properties of upholstery furniture leather

Sample test	Variable		Adhesion (N)	Rubbing fastness			Glossy test
	Silicon	Crosslinker		Sweat	Wet	Dry	
Sample A	3%	2%	4.83	4	4.25	5	2
Sample B	4%	2%	4.49	4	4	5	2.1
Sample C	3%	3%	6.04	4	5	5	1.9
Sample D	4%	3%	6.34	5	5	5	2.1
Standard customer			>2.5	Min 4	Min 4	Min 4	1.8-2.2

Silicone and crosslinker in the top coat improve leather quality by increasing layer adhesion.

Figure 1(a) shows a positive correlation between crosslinker and silicone to adhesion value. The maximum adhesion value of 6.34 N was achieved with 3% crosslinker and 4% silicone. Crosslinkers enhance adhesion by facilitating the penetration of finishing materials into the leather [15]. The crosslinker used in this study is a member of the isocyanate group, where the crosslink between the hydroxyl group (-OH) on the binder will form a crosslink with the -NCO group on the isocyanate. The crosslinking that occurs is expected to reduce delamination in the finished leather article upholstery [14]. Statistical analysis showed that the crosslinker and silicone fulfilled normal distribution data with a p-value> 0.05. Therefore, ANOVA test can be conducted to determine the significance of variables on adhesion. The p-value of the ANOVA was 0.789 for silicone and 0.024 for crosslinker, while the interaction between these two had a p-value of 0.309. This shows that only crosslinker has a significant effect on adhesion, with a p-value <α (0.024<0.05)

Rubbing fastness

Rubbing fastness evaluations were conducted utilizing sweat, wet, and dry treatments. Each treatment—sweat, wet, and dry—employs distinct cycle counts; specifically, the sweat treatment consists of 80 cycles, the wet treatment 250 cycles, and the dry treatment 500 cycles. The purpose of conducting rubbing fastness test is to ascertain the fastness characteristics of the leather material. As shown in **Figure 1(b)** and **Table 5**, the outcomes of the rubbing fastness on upholstery leather, which incorporated silicone and crosslinker in the uppermost coating, are obvious. **Figure 1** shows that an increase in the quantities of crosslinker and silicone correlates with an enhancement in the fastness of the leather. Sample D, which incorporated 4% silicone and 3% crosslinker, yielded the most favorable results in the rubbing fastness assessment. A higher value of rubbing fastness indicates greater fastness properties [16]. This suggests a direct correlation between

Crosslinker addition and enhanced interlayer bond strength in finished leather. Additionally, the number of crosslinks formed also improved rubbing fastness properties of the material [17]. Statistical analysis indicated no influence of crosslinker and silicone on rubbing fastness.

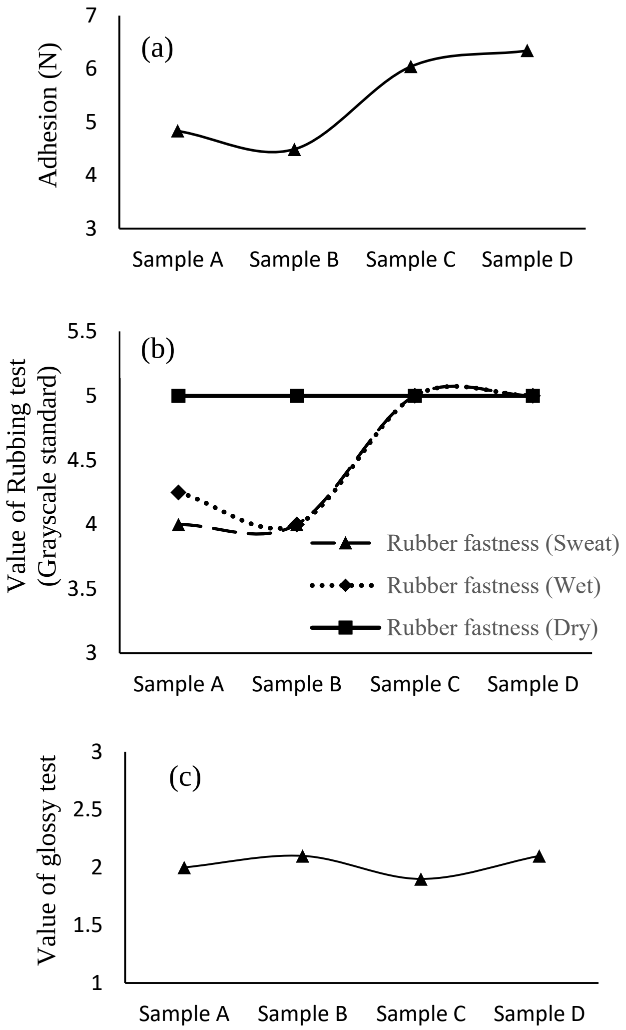

Figure 1. Result of physical properties of leather sample, (a) Adhesion; (b) Rubbing fastness; (c) Glossy test.

Glossy test

Glossy testing is performed to determine the extent of glossiness by the skin, with the consumer standard defined as a glossy test value ranging from 1.8 to 2.2. As shown in **Table 5**, the glossy test outcomes indicate that samples A, B, C, and D have satisfied the specified customer standards. Furthermore, as illustrated in **Figure 1(c)** and **Table 5**, samples B and D exhibit identical glossy test values, thereby suggesting that the incorporation of silicone has the potential to enhance the glossiness level in skin testing. It can be inferred that sample D yields the most favorable results, by the addition of 3% crosslinker and 4% silicone. According to statistical analyses, there appears to be no significant influence of crosslinker and silicone on the glossy assessment.

CONCLUSION

The addition of crosslinker and silicone influences leather's physical properties and abrasion resistance. The optimal results were observed in upholstery leather sample D with 3% crosslinker and 4% silicone, showing excellent abrasion and adhesion values, alongside satisfactory characteristics in slipperiness, rubbing fastness, glossy value, and flexing resistance. Multinomial logistic regression analysis suggested that silicone and crosslinker had no significant effect on abrasion resistance, whereas crosslinker has significantly affected slipperiness. The ANOVA analysis revealed that only crosslinker affected adhesion value, while no significant effects of crosslinker and silicone were found in rubbing fastness and glossy tests.

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