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Image Processing Based Scrub Tester Design and Production

Dizajn i izrada uređaja za ispitivanje otpornosti površine na struganje na temelju obrade slike

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ABSTRACT • *Determining how resistant paint, varnish or coating type materials, applied to wood-based panel surfaces, are to the effects of exposure to household chemicals is important in terms of developing products and providing durable surface coating to users. Every paint or coating type product coming off the production line needs to be tested quickly, and a new direction should be given to the work based on the positive or negative results obtained. Products without quality monitoring are returned by customers due to insufficient performance, resulting in loss of time, labor and materials. In this study, an Image Processing Based Scrub Tester (IPBST) was designed and produced in order to imitate the effect of paint, varnish and coating materials on the surfaces of furniture and decoration elements used in daily life against household chemicals. Unlike its counterparts, with IPBST, the image of each sample is digitally recorded before and after the scrubbing process, thanks to the "compact photo booth" integrated into the device. Wear, color and brightness change analyses of sample images can be performed with the "Surface Flaw Analysis (SFA)" method developed using the Matlab Graphical User Interface (GUI) image processing program on a computer integrated into the device. In this way, a 4-in-1 device that can do the job of 4 devices has been provided to the relevant scientific community and industry without the need for different types of industrial test devices.*

KEYWORDS: *scrub tester; image processing technique; household chemicals; wear; color and brightness test*

SAŽETAK • *Utvrđivanje otpornosti premaza na drvnim pločama na kemikalije u kućanstvu važno je za razvoj proizvoda i osiguranje trajnosti površinskog premaza tijekom uporabnog vijeka tih drvnih proizvoda. Svaki površinski obrađen proizvod koji izlazi s proizvodne trake potrebno je brzo ispitati kako bi se proizvodnja nesmetano nastavila na temelju dobivenih pozitivnih ili negativnih rezultata. Kupci vraćaju proizvode zbog neodgovarajućih svojstava, što je posljedica nedostatka kontrole kvalitete te rezultira gubitkom vremena, rada i materijala. U ovoj je studiji dizajniran i izrađen uređaj za ispitivanje otpornosti površina na struganje zasnovan na obradi slike (IPBST) kako bi se oponašao utjecaj kemikalija u kućanstvu na lakirane površine namještaja i dekorativnih elemenata. Za razliku od drugih metoda, s IPBST-om se slika svakog uzorka digitalno snima prije i nakon procesa struganja zahvaljujući kompaktnoj fotokabini integriranoj u uređaj. Razina istrošenosti, promjena boje i svjetline uzoraka na slikama mogu se provesti metodom analize površinskih grešaka (SFA) koja je razvijena primjenom programa za obradu slike Matlab Graphical User Interface (GUI) na računalu integriranom s uređajem. Time je zainteresi-*

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ranoj znanstvenoj zajednici i industriji predstavljen uređaj koji istodobno može obavljati posao četiriju uređaja, bez potrebe za različitim vrstama industrijskih ispitnih uređaja.

KLJUČNE RIJEČI: *uređaj za ispitivanje otpornosti površine na struganje; tehnika obrade slike; kemikalije u kućanstvu; istrošenost; ispitivanje boje i svjetline*

1 INTRODUCTION
1. UVOD

To utilize wood-based panels for furniture manufacturing and interior reinforcement, it is imperative to apply coatings or paint to both the surfaces and edges of the panels.

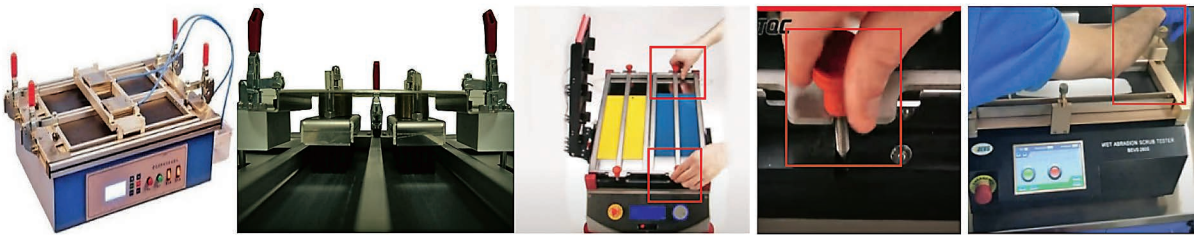
The materials applied to the panel surfaces serve various purposes, including enhancing the mechanical and physical properties of the panels, boosting the product's aesthetic value, providing a natural wood-like appearance and warmth, and ensuring consistency in color and pattern across the panel surfaces (Budakçı, 2010).

These applications, which aim to increase and protect the aesthetic value of wooden panels, deform and degrade over time depending on the performance of the materials used. In addition, the strength, interaction and quality of these materials, to which various coating, dyeing and printing techniques are applied, are effective in the rapid or slow development of the degradation process. In this context, a range of tests (brightness, hardness, roughness, color, adhesion, etc.) are conducted to evaluate the effectiveness of the protective coatings applied to the upper surfaces of wood materials or wood-based panels. Moreover, these materials undergo artificial or natural aging processes, including exposure to outdoor conditions, effects of rain or snow water, UV radiation from sunlight, accelerated salt corrosion, aging, temperature variations, household chemicals and abrasion. Consequently, various distortions can occur in the protective layers (Bayraktar and Kesik, 2022; Büşra *et al*., 2022; Özdemir *et al.,* 2018).

Nowadays, there is a wide variety of methods or devices available for testing resistance to household chemicals. In the paint / coating industry, wet scrubbing test devices are used to determine in advance the performance of a newly produced product in its environment. These devices are used to test the wear resistance of paints, varnishes and other coatings under wet conditions. Painted/coated samples are scrubbed with an abrasive pad specified in the standards, usually with a solution containing water or detergent. The weight pressure on the sample panel, scrubbing time and speed can be adjusted according to the standard principles of the selected test. After performing the accelerated aging process with scrubbing test devices, changes such as scratch depth, wear amount, color and brightness loss on the sample surfaces are measured. These measurements must be made using stereo microscope, SEM, color, brightness and roughness devices.

In prior research, Redsve *et al.* (2003) conducted cleanability tests on ceramic tiles using an Erichsen scrubbing device with a microfiber mop and two different chemical agents. Kok and Young (2014) employed a wet scrubbing test to assess the cleanability of insect residue on aircraft wing coatings, utilizing a Zeiss LSM 710 confocal laser scanning microscope and weight measurements of experimental samples. Marco *et al.* (2015) adhered to ISO 11998 standards, conducting 500 cycles of scrubbing on glass panels with chemical liquid and 3M dish washing sponges, analyzing surface changes with scanning electron microscopy (SEM). Santos *et al.* (2019) used a Leneta wet scrubbing test device to evaluate water-based paint dirt retention, employing a BYK color measuring device for assessing color differences. Helwani *et al.* (2021) employed "the BGD 526 wet scrubbing tester" to examine the brightness and washability of PVAc paint, measuring brightness according to Indonesian standard SNI 3564:2009. In the studies conducted, it was seen as a major problem that the scrubbing test devices used today cannot test the changes in the samples after the scrubbing process, cannot show any reference point and cannot produce a report and output.

In this study, "Image Processing Based Scrub Tester (IPBST)" was designed and produced in order to imitate the effect of painted or coated panels against household chemicals and to see the damage in a short time. The development of this tester received funding from the Scientific and Technological Research Council of Turkey (TUBITAK) under project number 221O551. Unlike its counterparts, digital images of each sample are recorded with the "compact photo booth" integrated into the device before and after the scrubbing process. A method named "Surface Flaw Analysis (SFA)" was developed using the Matlab GUI image processing program on a computer integrated into the device. With this method, wear, color and brightness change analyses of sample images were made possible. Thus, after the scrubbing process is applied to the sample surfaces, the amount of brightness, color and wear on the sample surfaces are determined without the need for a different testing device, and an output/report with numerical data is obtained. In this way, an innovative and original contribution to the industry has been made by reducing labor, reducing research costs and saving time.



a) b) c) d) e)

Figure 1 Working position of scrubbing head on sample surface (a, b), fixing of samples (c, d, e) (Alibaba, 2023; Mikroskopik, 2023)
Slika 1. Radni položaj glave za struganje na površini uzorka (a, b), fiksiranje uzoraka (c, d, e) (Alibaba, 2023.; Mikroskopik, 2023.)

2 CURRENT TECHNOLOGIES USED IN SCRUBBING PROCESSES
2. DANAŠNJE TEHNOLOGIJE ZA TESTIRANJE OTPORNOSTI POVRŠINE NA STRUGANJE

Wet scrubbing tester is a device used to determine the wear/aging resistance of the material surface (Figure 1a). It is a type of aging test method generally used to determine the wear/aging resistance of paint, varnish or similar coatings. A scrubbing head with an abrasion pad/brush under a certain weight pressure is moved on the coated sample surfaces prepared for testing. During this movement, a liquid is added between the sample and the etching pad. Then, the wear/aging resistance of the sample is monitored over a specific cycle and time interval according to the standards used in the study (Parvate and Mahanwar, 2019; Uytterhoeven *et al., 2002)*.

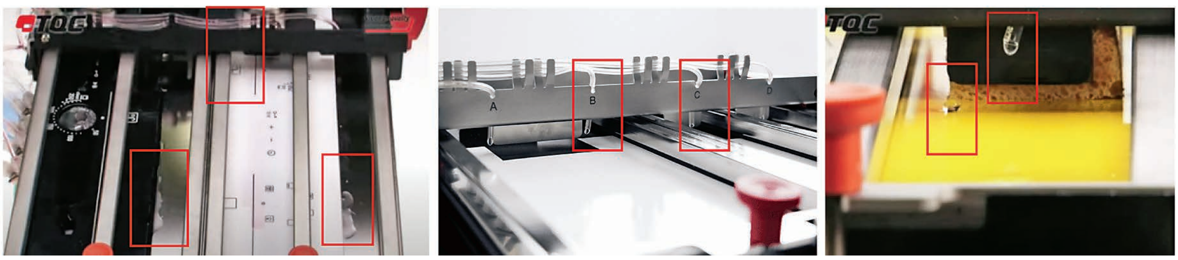
Scrub testers are used in industry to determine the quality of coating materials, evaluate the effectiveness of surface treatments, and measure the wear/aging performance of materials. It is an important test method used especially in areas such as the automotive industry, furniture industry, paint and coating industry (Smith *et al.,* 2017).

In order to carry out the resistance tests of painted/coated sample surfaces against household chemicals in the test devices as shown in Figure 1a-e, various abrasive equipment such as brush, felt, sponge pad, and sandpaper are used, and applications are carried out wet or dry. However, after the wet/dry scrubbing processes applied in these devices, it was observed that the entire sample surface area could not be aged by scrubbing. This is due to the fact that the samples placed in the device are compressed with a pressure arm coming from above to prevent them from moving during scrubbing (Figure 1c, d and e). In addition, this mechanical pressure on the sample surface causes deformations in the paint/varnish/coating film layer. This causes the chemicals used in the experiments to deform the material surfaces differently, resulting in misleading results.

In the existing scrubbing devices, it has been observed that during the back-and-forth movement of the scrubbing head during the wet scrubbing process, the chemical that should drip onto the surface often does not drip onto the sample. It was observed that the drops falling on the painted sample bounced with the force of the impact and dispersed on the device (Figure 2a, b and c). It is thought that this situation is caused by the incorrect design of the liquid flow/drip system (Figure 2a).

Another negative situation is that the platforms on which the samples seen in Figure 1.a, b and d and Figure 2a are placed cannot be adjusted parametrically. Due to this situation, researchers are forced to prepare samples according to the device.

The most important deficiency in scrubbing test devices is that these test devices only perform abrasion by wet/dry scrubbing and cannot produce a quantitative result report/output for the test samples as a result of this process. When the working principles of scrub testers are examined, it is observed that they cannot go beyond automation according to the principles of Industry 4.0 (Jeon *et al.,* 2020; Lin *et al.,* 2019).



a) b) c)

Figure 2 Liquid dropping on sample surfaces (a, b, c) (Karkimya, 2023; Satatonmall, 2023)
Slika 2. Kapanje tekućine na površinu uzoraka (a, b, c) (Karkimya, 2023.; Satatonmall, 2023.)

3 IMAGE PROCESSING BASED SCRUB TESTER (IPBST)
3. UREĐAJ ZA ISPITIVANJE OTPORNOSTI POVRŠINE NA STRUGANJE NA TEMELJU OBRADE SLIKE

In this study, IPBST was produced and designed in order to imitate the effect of materials such as coating, paint and varnish on the surfaces of furniture and decoration elements used in homes in daily life against household chemicals (Figure 3a and Figure 3b).

AutoCAD and Solidworks 3D modeling programs were used to model, project and simulate the device. Thanks to simulations made with design programs, issues that may pose problems during production and possible situations that may be encountered in the innovative aspect of the device were recognized at the design stage, and technical solutions were developed accordingly. Considering the commercial potential of the tester, its name was determined as "Image Processing Based Scrub Tester" and the abbreviation term was determined as "IPBST".

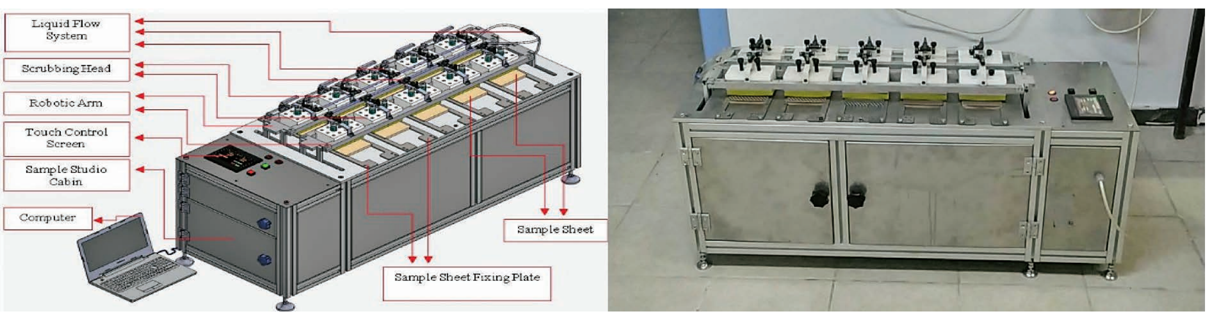
The parameters required for the tester to operate while scrubbing the sample surfaces are: Parameters that can be adjusted such as movement speed, time, revolutions, liquid flow rate. By changing the parameters in the IPBST device such as weight, scrubbing speed, number of scrubbing cycles, it is adjusted according to American Society for Testing and Materials Standard (ASTM) D2486, ASTM D3450, ASTM D4213, ASTMD 4828, German Standardization (DIN) EN 11330 and Turkish Standard (TS EN) ISO 11998 wet scrubbing standards and tests are carried out accordingly (Francone *et al.,* 2021; Uytterhoeven *et al.,* 2002).

Scrub test devices currently used in scrubbing processes cannot measure and provide numerical data on changes such as color, brightness, roughness and scratching that occur on the sample surface after physically aging the painted, varnished, coated sample surfaces with chemical liquid and abrasive pad. Experts in quality control laboratories in the industry and/or researchers in the scientific community complete the scrubbing process of the samples. Then, it is seen that researchers have to make measurements and produce data using devices such as color, brightness, roughness, stereo microscope and SEM in order to detect the changes occurring on the surface of these samples (Helwani *et al.,* 2021; Kok and Young, 2014; Marco *et al.,* 2015; Redsve *et al.,* 2003; Santos *et al.,* 2019).

IPBST was developed with the aim of performing the scrubbing process on sample panel surfaces (accelerated aging) and obtaining numerical results of the wear, color and brightness changes that occur on the material surfaces due to the scrubbing process. In this way, a new and unique tester is planned to be introduced to industry. Although IPBST is basically designed for scrubbing and aging painted and coated wooden surfaces, it also has an infrastructure that can be used for scrubbing materials such as plastic, glass and metal. Thus, the device is expected to have a very wide use in industry.

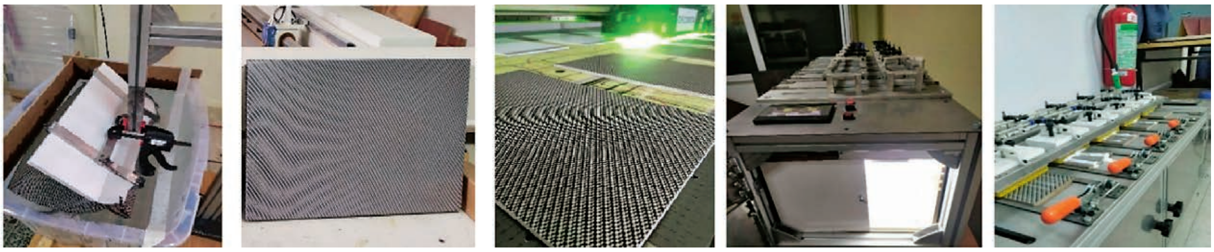
3.1 Test device working principle
3.1. Načelo rada ispitnog uređaja

The working principle of IPBST is based on TS EN ISO 11998 (2006) standard. In accordance with the standard, a scrubbing unit weighing (135±1) g in total, including a 70 g scrubbing head, a 10 g abrasive sponge pad and a 55 g weight apparatus, is contacted to the painted / varnished / coated sample surfaces. During the scrubbing process, approximately 5 ml of liquid is transferred to the surface of the painted samples by using household chemicals specified in the ASTM D1308-20 (2020) standard. The scrubbing heads execute a smooth linear motion, moving back and forth on the +Y and –Y axis at a rate of (37±2) cycles per minute, totaling 200 cycles. It has been reported in the literature that surfaces scrubbed with these parameters are very effective on wear, scratching, color, brightness and roughness values (Mermer *et al.,* 2023; Popa *et al*., 2021; Zettl, 2014). In addition, it is seen that researchers use many different brands of devices in wet scrubbing tests and perform different scrubbing processes according to many



a) b)

Figure 3 Image processing based scrubbing tester (IPBST) design (a), IPBST (b)
Slika 3. Dizajn uređaja za ispitivanje otpornosti površine na struganje na temelju obrade slike (a), IPBST (b)



a) b) c) d) e)

Figure 4 Example of WTP (a, b), example of UV printing process (c), scrubbing process application (d), IPBST compact photo booth (e)

Slika 4. Primjer vodenoga prijenosnog tiska (a, b), primjer procesa UV ispisa (c), primjena procesa struganja (d), IPBST kompaktna fotokabina (e)

standards depending on the purpose of the subject. Depending on the standards they use, it appears that they vary the scouring pad/brush, weight masses, scouring speed and duration (Cayton and Sawitowski, 2005; Shi *et al.,* 2013; Wen *et al.,* 2022).

With the IPBST, digital images are captured before and after the scrubbing process within the integrated compact photo booth to evaluate the effectiveness of protective layers on sample surfaces. After the scrubbing process, wear, color and brightness change analyses of the sample images are performed with a method called "SFA" using the Matlab GUI image processing program on the computer integrated into the device. No wet scrub tester used in the industry has such a capability. Thanks to IPBST, whose design and production has been completed, numerical data is produced based on image processing to measure the amount of wear, color and brightness of paint/coating types without using a different test device. In this way, reducing tiring manpower and saving time and equipment will provide an innovative and original contribution to the sector. The different aspects of the device produced within the scope of the research from its counterparts in the industry are presented under headings in the following sections of the study.

4 MATERIALS AND METHODS
4. MATERIJALI I METODE

4.1 Preparation of samples and scrubbing process
4.1. Priprema uzoraka i proces struganja

In order to evaluate the performance of IPBST after its production, sample parts were prepared, and preliminary studies were carried out on these samples. Various types of Medium-Density Fiberboard (MDF) panels commonly used in the furniture industry, including first-class 8 mm thick bright white PVC coated MDF, high gloss acrylic coated MDF, MDF ready-to-use laminate panels, and raw MDF panels, were used. These samples, measuring 520 mm × 310 mm, were conditioned in an air-conditioned cabinet until reaching a constant weight and reducing their moisture content to 9 to 10 %, in accordance with the Turkish Standard (TS) EN 322 (1999). A protective layer, consisting of glossy white polyurethane, acrylic, cellulosic, and water-based lacquer paint, was applied to all raw MDF panels following the ASTM D3023-98 (2017). Subsequently, these lacquered samples were acclimatized to 9 to 10 % moisture content first at room conditions and then in the air-conditioned cabinet.

Carbon fiber patterned decorative coating was applied to the sample surfaces using both water transfer printing (WTP) and ultraviolet (UV) printing methods, as depicted in Figures 4a, b, and c. These methods were cited in the references (Kaçamer, 2024; Kaçamer *et al.,* 2024; Kaçamer and Budakçı, 2023). A total of 980 samples were prepared for the experimental groups, comprising two different decorative coating types, seven different panel types, and seven different household chemical types.

Before starting the scrubbing process, digital images of the sample panels were captured using the compact photo booth integrated into the device (Figure 4d). Subsequently, these samples underwent exposure to various household chemicals using the IPBST. The scrubbing operation involved a (135±1) g scrubbing head unit in accordance with TS EN ISO 11998 (2006) standards. A 3M dish washing sponge served as the scrubbing pad. Scrubbing was carried out by the scrubbing heads executing 200 smooth linear movements, oscillating between the +Y and – Y axis, at a frequency of (37±2) cycles per minute. Household chemicals including cola, lemon juice, dishwashing liquid, bleach, acetone, and ethyl alcohol were used for scrubbing in accordance with ASTM D1308-20 (2020) standards. Each sample surface received 5 mL of these chemicals (Figure 4e).

Considering the preparatory work, the differences in the types of household chemicals used in the scrubbing process were reflected in the data obtained in the measurements. The effect of each household chemical on accelerated aging has been found to be different.

4.2 Tests
4.2. Testovi

A method named "SFA" was developed using the image processing technique and the Matlab GUI image processing program, and the wear, color and brightness changes of the recorded sample images were analyzed. In addition, Zeiss Axio Scope A1 brand stereo microscope and BYK Gardner Spektro-Guide 45/0 device (Spectro-guide sphere gloss meter, model CD-6834. BYK-Gardner GmbH, Geretsried, Germany), which are industrial testing devices, were used to test the accuracy of the SFA method. With these devices, wear (ASTM E112-13, 2013), color (ASTM D2244-21, 2022) and brightness (TS EN ISO 2813, 2014) measurements were made (Figure 5). For the wear test, coating film thicknesses were measured in micron (μm) units and then wear rates were calculated by calculating the wear rates as percentages (%). For the color test, the result was obtained by calculating the total color change (ΔE^*). For the brightness test, the percentage (%) of the numerical data taken before and after the scrubbing process on the surfaces of the sample boards was calculated.

5 RESULTS AND DISCUSSION
5. REZULTATI I RASPRAVA

The data collected in this study were analyzed using the SPSS 24 statistical package program (IBM, 2021). Pearson Correlation analysis was carried out to determine the relationship between the data of wear, color and brightness tests performed with IPBST and hand data from industrial testing devices. The findings obtained are given in Table 1.

According to the results of Table 1, a robust and statistically significant positive relationship (P<0.01) was determined between two different wear measurement methods, statistically 0.81, and between two different color measurement methods, statistically 0.97.

Furthermore, a strong and statistically significant positive correlation of 0.71 (P<0.01) was observed between the two distinct brightness measurement techniques. These correlation findings are illustrated in Figures 6a, b and c.

The result of the correlation graph given in Figure 6.a.b.c proves that the wear, color and brightness measurement method with IPBST can be used without the need for other industrial type devices.

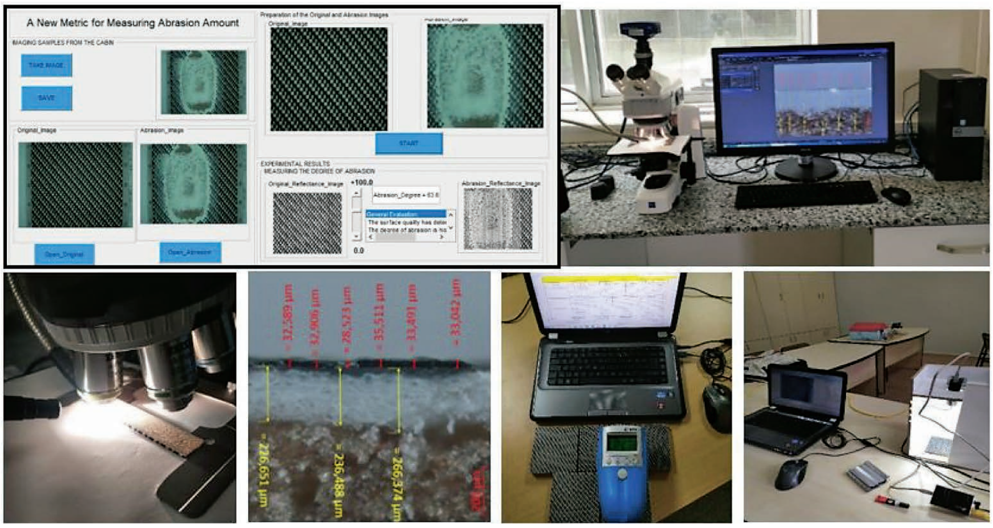
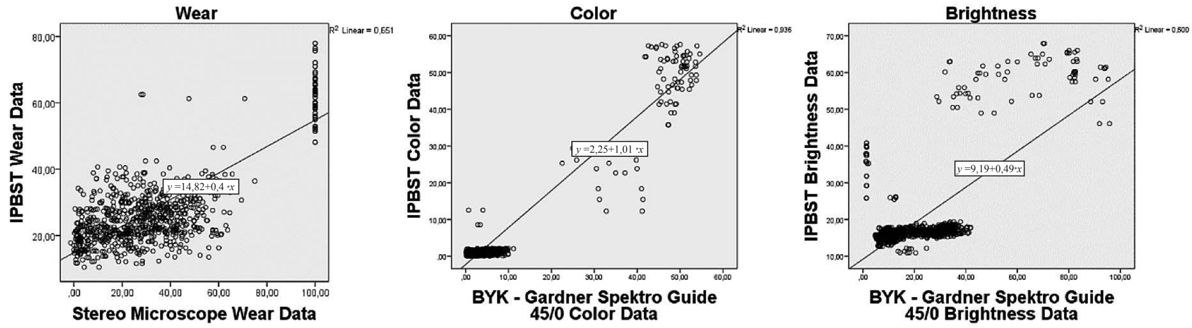


Figure 5 Wear, color and brightness tests before and after scrubbing
Slika 5. Testovi istrošenosti, boje i svjetline prije i nakon struganja

Table 1 Relationship between IPBST measurement method and measurements of industrial test devices
Tablica 1. Odnos između IPBST metode mjerenja i mjerenja industrijskim ispitnim uređajima

Measurement methods *Metode mjerenja*	**Correlation coefficient (*r*)** *Koeficijent korelacije (r)*	***P* Value** *P-vrijednost*	**Sample measurement amount (*n*)** *Broj izmjerenih uzoraka (n)*
Wear / *istrošenost* (IPBST – Stereo Microscope)	0.81	0.000*	1680
Color / *boja* (IPBST – BYK Gardner Spectro-Guide 45/0)	0.97	0.000*	1680
Brightness / *svjetlina* (IPBST – BYK Gardner Spectro-Guide 45/0)	0.71	0.000*	1680

*Significant at $P < 0.01$ / *značajno pri P < 0,01*



a) b) c)

Figure 6 IPBST and stereo microscope wear data (a), IPBST and BYK gardner spectro-guide 45/0 color data (b), correlation relationship between IPBST and BYK gardner spectro-guide 45/0 brightness data (c)
Slika 6. Korelacija podataka o istrošenosti dobivenih IPBST uređajem i podataka sa stereomikroskopa (a), korelacija podataka o boji dobivenih IPBST uređajem i uređajem *BYK gardner spectro-guide* 45/0 (b), korelacija podataka o svjetlini dobivenih uređajem IPBST i uređajem *BYK gardner spectro-guide* 45/0 (c)

6 CONCLUSIONS
6. ZAKLJUČAK

As a result of the research, the wear, color and brightness changes on the material surfaces rubbed using various household chemicals with IPBST, designed and produced within the scope of the project, were compared with different industrial test devices, and similar and positive results were identified.

İt was determined that acetone was the chemical that caused the highest abrasion of the coated sample surfaces and color changes. It was also determined that dishwashing detergent caused the greatest decrease in gloss on coated surfaces. Furthermore, it was determined that lemon juice was the chemical that caused the least damage when cleaning the surface of coated panels. In addition, after scrubbing the coated sample panel surfaces with household chemicals, the UV printed samples showed better performance in wear, color and brightness tests than the WTP applied samples.

Thanks to IPBST, an accelerated aging (scrubbing process) was performed on the material surfaces. Thanks to the IPBST and SFA method developed with the original study, the data obtained as a result of the wear, brightness and color tests were analyzed quickly. In this way, a 4-in-1 device that can do the work of 4 devices, without the need for different types of industrial test devices, was presented to the relevant scientific community and industry. The ability of IPBST to perform the scrubbing process, as well as wear, brightness and color analyses is a gain for the world of science.

SFA, an advanced image processing-based technique, has significantly advanced the ability to measure wear, color, and brightness changes in the paint and coating industry. By offering a faster and more efficient method, SFA eliminates the need for costly instrumentation traditionally required for such assessments. This method is particularly well-suited for applications in woodworking, paint, varnish, and coating industries, as well as furniture manufacturing. Its adoption is expected to facilitate new research and development initiatives, thereby contributing to innovation in these fields.

Due to the effectiveness and innovative nature of IPBST, industrial organizations and researchers involved in mass production within the paint and coating sector have achieved significant time savings and simplified processes. This advancement has enabled researchers to conduct studies on wear, color, and brightness measurement without relying on expensive equipment, leading to substantial cost reductions.

Thanks to remote sensing of PBST, it can be emphasized that it is a candidate to be a new and widely used wear, color and brightness measurement system that can provide increasing occupational safety and ease of use.

The scrubbing head weights, scrubbing pad, number of scrubbing cycles and speed of IPBST produced are designed to be changeable according to different materials and different standards. In this way, wet or dry scrubbing can be done, and new research opportunities can be provided for different studies. The hardware can be enriched by preparing a precision scale or a mechanism for micron measurement on the main body of IPBST for wear control.

Additionally, experiments can be carried out on different material surfaces (plastic, wood, metal fabric, etc.) using different types of chemicals with IPBST. In the scrubbing process, instead of a sponge, a brush, sandpaper or steel wool can be preferred. Experiments can be carried out using bacteria, virus and germ inhibiting chemicals, especially in health, food and laboratory areas where hygiene conditions are important. It may be recommended to develop and research method with different algorithms in programs such as MATLAB, OpenCV, Python to perform tests such as surface roughness, hardness and scratching with SFA.

Acknowledgements – Zahvala

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7 REFERENCES
7. LITERATURA

1. Bayraktar, D. K.; Kesik, H. İ., 2022: Color change against the natural aging effect of water-based protective layers on some etched wood materials. Anatolian Journal of Forest Research, 8: 46-52 (in Turkish). https://doi.org/10.53516/ajfr.1198142
2. Budakçı, M., 2010: The determination of adhesion strength of wood veneer and synthetic resin panel (laminate) adhesives. Wood Research, 55: 125-136.
3. Büşra, A.; Çavdar, A. D.; Mengeloğlu, F., 2022: The properties of wood polymer composites after natural and artificial weathering. Turkish Journal of Forestry Research, 9: 264-270 (in Turkish). https://doi.org/10.17568/ogmoad.1091198
4. Cayton, R. H.; Sawitowski, T., 2005: The impact of Nano-materials on coating technologies. TechConnect Briefs, Technical Proceedings of the 2005 NSTI Nanotechnology Conference and Trade Show, 2: 83-85.
5. Francone, A.; Merino, S.; Retolaza, A.; Ramiro, J.; Alves, S. A.; de Castro, J. V.; Neves, N. M.; Arana, A.; Marimon, J. M.; Torres, C. M. S., 2021: Impact of surface topography on the bacterial attachment to micro- and nano-patterned polymer films. Surfaces and Interfaces, 27: 101494. https://doi.org/10.1016/j.surfin.2021.101494
6. Helwani, Z.; Fadhillah, I.; Wiranata, A.; Miharyono, J., 2021: Opacity and washability properties of emulsion paint with natural rubber latex/polyvinyl acetate blend binder. Journal of Physics: Conference Series, IOP Publishing, 012092. https://doi.org/10.1088/1742-6596/2049/1/012092
7. Jeon, B.; Yoon, J.-S.; Um, J.; Suh, S.-H., 2020: The architecture development of Industry 4.0 compliant smart machine tool system (SMTS). Journal of Intelligent Manufacturing, 31: 1837-1859. https://doi.org/10.1007/s10845-020-01539-4
8. Kaçamer, S., 2024: Investigation of the use of hydrographic coating (water transfer printing) and ultraviolet (UV) printing process on furniture surfaces. PhD Thesis, Düzce University, Düzce, Türkiye.
9. Kaçamer, S.; Budakçı, M., 2023: Application parameters of water transfer printing on wood-based panel surfaces. BioResources, 18: 1025. https://doi.org/10.15376/biores.18.1.1025-1040
10. Kaçamer, S.; Katırcıoğlu, F.; Budakçı, M., 2024: Determining abrasion resistance of decorative coated wood-based panels using retinex model. BioResources, 19: 1058-1078.
https://doi.org/10.15376/biores.19.1.1058-1078
11. Karkimya, 2023: Scrub and cleanability tester. https://www.karkimya.com.tr/tr/urunler/surtunme-ovalama-dayanimi/tqc-scrub-test-cihazi (Accessed Nov. 26, 2023).
12. Kok, M.; Young, T. M., 2014: Evaluation of insect residue resistant coatings – Correlation of a screening method with a conventional assessment technique. Progress in Organic Coatings, 77: 1382-1390. https://doi.org/10.1016/j.porgcoat.2014.04.020
13. Lin, J.-W.; Liao, S.; Leu, F.-Y., 2019: Sensor data compression using bounded error piecewise linear approximation with resolution reduction. Energies, 12 (13): 2523. https://doi.org/10.3390/en12132523
14. Marco, J. M.; Bellido-González, V.; Sorzabal, I.; Alonso, R.; Cueva, A., 2015: Effects of ion bombardment pretreatment on glass coating processes and post tempering. Society of Vacuum Coaters 505/856-7188, 58th Annual Technical Conference Proceedings, Santa Clara, CA April 25-30, pp. 177-181. http://dx.doi.org/10.14332/svc15.proc.1935
15. Mermer, N. K.; Ugur, N.; Kuzgun, F.; Bakar, B.; Inceoglu, F.; Pinar, E. U., 2023: Evolution of coalescent agent-free ultra-low VOC paint with formaldehyde capturing properties. Atmospheric Pollution Research, 14 (8): 101812. https://doi.org/10.1016/j.apr.2023.101812
16. Mikroskopik, 2023: Multi-function wear testing device. https://www.mikroskopik.com/Products/Ovalama-Test-Cihazi-350.html (Accessed Nov. 26, 2023.
17. Özdemir, F.; Ramazanoğlu, D.; Tutuş, A., 2018: Investigation of the effect of aging time, sanding and cross section on the surface quality of fir wood. Journal of Bartin Faculty of Forestry, 20: 194-204. https://doi.org/10.24011/barofd.426013
18. Parvate, S.; Mahanwar, P., 2019: Insights into the preparation of water-based acrylic interior decorative paint: tuning binder's properties by self-crosslinking of allyl acetoacetate-hexamethylenediamine. Progress in Organic Coatings, 126: 142-149. https://doi.org/10.1016/j.porgcoat.2018.10.014
19. Popa, S.; Radulescu-Grad, M. E.; Perdivara, A.; Mosoarca, G., 2021: Aspects regarding colour fastness and adsorption studies of a new azo-stilbene dye for acrylic resins. Scientific Reports, 11: 5889. https://doi.org/10.1038/s41598-021-85452-7
20. Redsve, I.; Kuisma, R.; Laitala, L.; Pesonen-Leinonen, E.; Mahlberg, R.; Kymäläinen, H.-R., Hautala, M.; Sjöberg, A.-M., 2003. Application of a proposed standard for testing soiling and cleanability of resilient floor coverings. Tenside Surfactants Detergents, 40: 346-352. https://doi.org/10.1515/tsd-2003-400607
21. Santos, J. P.; Paula, N. F.; Pagani, R. A.; Caldato, R. A.; Da Silva, R.; Barrios, S. B., 2019: Low-VOC Coalescents. Coating World-Technical Paper, 267-302.
22. Shi, Y.; Song, Z.; Zhang, W.; Song, J.; Qu, J.; Wang, Z.; Li, Y.; Xu, L.; Lin, J., 2013: Physicochemical properties of dirt-resistant cool white coatings for building energy efficiency. Solar Energy Materials and Solar Cells, 110: 133-139. https://doi.org/10.1016/j.solmat.2012.12.011
23. Smith, G.; Lentz, T.; Assembly, F. C. T., 2017. An Investigation into the durability of stencil coating technologies. In: Proceedings of IPC Apex Expo Technical Conference, S21-02, San Diego, CA, pp. 12-16.
24. Uytterhoeven, G.; Fonzé, A., Petit, H., 2002: Acid and scratch resistant coatings for melamine based OEM applications. Macromolecular Symposia, Wiley Online Library, pp. 515-530.
25. Wen, J.; Khan, A. D.; Sartorelli, J. B.; Goodyear, N.; Sun, Y., 2022: Aqueous-based continuous antimicrobial finishing of polyester fabrics to achieve durable and rechargeable antibacterial, antifungal and antiviral functions. Journal of Industrial and Engineering Chemistry, 107: 249-258. https://doi.org/10.1016/j.jiec.2021.11.050
26. Zettl, M., 2014: High performance coatings for solar receivers and new dedicated manufacturing solution. En-

ergy Procedia, 48: 701-706. https://doi.org/10.1016/j.egypro.2014.02.081
27. ***Alibaba, 2023: Wet wear and scrub resistance tester. https://turkish.alibaba.com/product-detail/wet-abrasion-and-scrub-resistance-tester-60715227003.html?spm=a2700.8699010.normalList.19.51f650f7FFV82X (Accessed Nov. 26, 2023).
28. ***ASTM D1308-20, 2020: Standard Test Method for Effect of Household Chemicals on Clear and Pigmented Coating Systems. ASTM International, West Conshohocken, PA, USA.
29. ***ASTM D2244-21, 2022: Standard Practice for Calculation of Color Tolerances and Color Differences from Instrumentally Measured Color Coordinates. ASTM International, West Conshohocken, PA, USA.
30. ***ASTM D3023-98, 2017: Standard Practice for Determination of Resistance of Factory-Applied Coatings on Wood Products to Stains and Reagents. ASTM International, West Conshohocken, PA, USA.
31. ***ASTM E112-13, 2013: Is There Possible Bias in ASTM E112 Planimetric Grain Size Measurements. ASTM International, West Conshohocken, PA, USA.
32. ***IBM, 2021: Downloading IBM SPSS Statistics 24. https://www.ibm.com/support/pages/downloading-ibm-spss-statistics-24 (Accessed Nov. 7, 2023).
33. ***Satatonmall, 2023. Abrasion Washability Tester. https://www.satatonmall.com/p/abrasion-washability-tester.html (Accessed Nov. 26, 2023).
34. ***TS EN 322, 1999: Wood based boards-Determination of moisture content. Turkish Standards Institute, Ankara, Türkiye.
35. ***TS EN ISO 2813, 2014: Paints and varnishes – Gloss determination of non-metallic paint films at 20, 60 and 85 angles. Turkish Standards Institute, Ankara, Türkiye.
36. ***TS EN ISO 11998, 2006: Paints and varnishes – Determination of wet-scrub resistance and cleanability of coatings. Turkish Standards Institute, Ankara, Türkiye.

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