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Effect of the Layer Thicknesses on Surface Hardness of Oak Parquets Painted with Water Based Paint Mixed with Hollow Glass Spheres

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Abstract

Aim of study: Determination of the effect of different layer thicknesses on the surface hardness value of the water based paint mixed with hollow glass spheres (WBPHGS) applied to oak parquets.

Material and method: Two, four and six layers of WBPHGS and additionally one layer protective varnish were applied to the surfaces of parquet specimens produced from oak (*Quercus petraea* L.) wood. WBPHGS was preferred by reason of the fact that it does not harm environment and human health, and also it has not become widespread on usage of wood surfaces. The surface hardness resistance tests of WBPHGS were performed according to the ASTM D 2240 standard.

Results: The mean surface hardness values of oak parquet decreased as the layer thicknesses increased.

Highlights: To determine the applicability of WBPHGS which is widely used in the construction and machinery sectors to the surfaces of oak parquet and the surface hardness values of this paint.

Keywords: Oak Parquet, Water-Based Paint, Hollow Glass Spheres, Hardness

İçi Boşluklu Cam Kürecikli Su Bazlı Boya Uygulanmış Meşe Parkelerin Yüzey Sertlik Direnci Üzerinde Katman Kalınlığının Etkisi

Öz

Çalışmanın amacı: Meşe parkelere uygulanan içi boşluklu cam kürecikli su bazlı boyanın (WBPHGS) yüzey sertlik direncine, katman kalınlığının etkisini belirlemektir.

Materyal ve yöntem: Sapsız meşe (*Quercus petraea* L.) odunundan hazırlanarak üretilen parke yüzeylerine iki, dört ve altı kat WBPHGS ve ek olarak üst yüzeye bir kat koruyucu vernik uygulanmıştır. WBPHGS, çevre ve insan sağlığına zarar vermediği ve ayrıca ahşap yüzeylerde kullanımı yaygın olmadığı için tercih edilmiştir. Meşe parke yüzeylerine farklı kalınlıklarda uygulanan WBPHGS'nin sertlik direnci testleri ASTM D 2240'a göre belirlenmiştir.

Temel sonuçlar: Meşe parke yüzeylerine uygulanan WBPHGS'nin katman kalınlığı arttıkça sertlik değerlerinin düştüğü tespit edilmiştir.

Araştırma vurguları: Günümüzde inşaat ve makine sektöründe yaygın olarak kullanılan WBPHGS'nin meşe parkelerin yüzeylerine uygulanabilirliğinin ve bu boyanın yüzey sertlik değerlerinin belirlenmesi.

Anahtar Kelimeler: Meşe Parke, Su Bazlı Boya, İçi Boşluklu Cam Kürecik, Sertlik

Introduction

There are many fields for usage of wooden material known for superior properties such as insulation material, the presence of wide range of colors, patterns and fragrances. These properties are observed in wooden material's mending, maintenance and processing qualities, being easy and mechanical resistance being high, good acoustic properties having a specific

heat, resistance to expansion by temperature change, and low thermal conductivity (Sönmez and Budakçı, 2004). In addition, wooden material has other properties such as, harmony with other reinforcement elements, durability (As, 1998; Döngel et. al., 2008) natural appearance, and feeling of warmth especially for flooring materials (parquet).

Density and hardness are two important factors affecting wear resistance. Resistance to crushing and abrasive effects on the surface of material depends on the density of wood. The resistance against to crushing and abrasive effects increases since hardness increases as a result of increases in density of wood (Kollman and Cote, 1968). Therefore, wear resistance is an important criterion when selecting the appropriate wood for parquet production. However, the resistance to abrasion is important in wood flooring which is not covered with a protective film, but the importance of the wood flooring with its surface is varied depending on the density of wood used in the flooring. Wear resistance of wood may not be important if it provides sufficient protection against abrasion on the surfaces with low density (Kurtoğlu and Ünlügil, 1991). For this reason, the place of use should be considered depending on the intensity of use when selecting the wood species to be used in parquet production. While hardness, abrasion resistance and dimensional stability come to the forefront in industrial areas, softwoods can easily be used because of the dimensional stability and aesthetic foreground in the houses (Kollman and Cote, 1968). The hardness values of 55.35 and 51.83 in the measurements made with the Shoremeter hardness meter can be easily used as parquet in the houses made of Scots pine and black pine (Saygın and Budakçı, 2017) while the average hardness value is 76 when oak wood is used which may result better in the case of parquet production (Karamanoğlu and Akyıldız, 2013).

It is possible to extend the life of the wood material and to increase the surface resistance by choosing suitable wood materials and using protective layer applications suitable for the usage.

Depending on today's technology, the development of the paint industry allows the paint to be used in many different application areas. The surface hardness values may sometimes be low or high compared to those not applied to the wood material to which the protective layer is applied. These changes in hardness values may depend on the layer thickness and protective layer cement.

While the hardness of the varnish layers used in wood is an important indicator for determining the durability of external factors (Budakçı, 1997), the decrease in surface hardness in protective layers weakens the impact resistance such as impact, scratching and friction (Özen and Sönmez, 1999). The effect of the varnish layer thickness on the abrasion resistance values is important, but the actual effect is depend on the wood species and varnish cementite (Tekin, 2009).

Although there is limited studies related to the WBPHGS applied to wooden materials, it is mostly used in the interior and exterior facades of thermal, acoustic and moisture isolation buildings the excess heat emitting motor, machine etc. in space and aviation products (Kabakcı and Kesik, 2020; Wang et al. 2014; Posmyk 2016; Kimetsan Technical Bulletin 2018). Accordingly; the aim of this study was to determine the applicability of WBPHGS, which is widely used in the construction and machinery sectors, to the surfaces of oak parquet which is used as floor covering and the surface hardness values of this paint.

Material and Method

Wood Material

Oak (*Quercus Petraea* Mill) wood was preferred as experimental material since it is widely used in the parquet industry. It has been noted that the wood material used in the experiments was selected randomly from timber enterprises with no damages such as smooth fiber, knots, cracks, color and density difference, reaction wood, fungi and insect damage.

Water-Based Paint Mixed with Hollow Glass Spheres (WBPHGS)

The WBPHGS used in the experiments was supplied by Kimetsan Technical Bulletin (2018). The company has defined it as a water based nano insulation paint which is made by using nano technology, micro-

technological acrylic modified polyurethane heat insulation and waterproofing insulation. Since the water-based nano insulation paint mixture has a structure with glass and ceramic spheres, the upper part appears as a solid layer when the package box is opened.

The paint was mixed well before the application. The used WBPHGS was a two-component material, the second component (hardener) being added at the application time. WBPHGS was applied with low pressure paint guns (nozzle diameter = 2.0 mm) and brush. It is important for the quality of the application to be 400-1000 microns thick depending on the region of energy loss and 30 minutes between layers of paint during application (Kimetsan Technical Bulletin, 2018).

The SEM (Quanta FEG 250; FEI Company, Brno, Czech Republic) image of the large and small microscale hollow glass spheres in the paint is shown in Fig. 1. All SEM images were captured at Kastamonu University Central Research Laboratory with the test specimens.

Preparation of the Specimens

Oak specimens were prepared according to TS ISO 3129 and TS ISO 13061-1 at a temperature of 20 ± 2 °C and a relative humidity of 65 ± 5%. Test specimens cut to net size were sanded with 180 and 220 sand, respectively. When preparing the paint, it is mixed until it becomes homogenous with a robust mixer, since the hollow glass spheres are collected at the upper part of the box when it is opened and form a hard layer. 0,5 liters of distilled water is added into the paint. The hardener is added up to 0.012 and the mixture is poured into 1 liter of paint. The test specimens prepared for the removal of the dusts were applied with a layer of filler (WBF-D 45) in order to make a good bond to the lining, then 2, 4 and 6 layers of WBPHGS and the last coat of varnish (WBV-D 45) were applied as a preservative. The application was made in multiples and the water in the paint was waited for 15 minutes between each coat until the vapor came out. The waiting period between layers will allow the glazing structure to accumulate on the surface of the box, thus ensuring a good mixing of the paint layer before each application process. WBPHGS is measured as 150 microns for each coat applied separately. The technical specifications of the paints, varnishes and applications used in the study are given in Table 1 (Kimetsan Technical Bulletin, 2018).

Table 1. Technical specifications for paints, varnishes and their applications

Protective Layer type	PH	Density (g/cm^3)	Viscosity (sec/DINCup/4mm)
WBF-D45	9.17	1.014	18
WBV-D45	9.10	1.015	18
WBNTP-D45	8.20	0.82	30

The SEM image of hollow glass spheres is given in Fig. 1. The SEM image of the WBPHGS applied to the test specimen is given in Fig. 2. The SEM image of the WBPHGS on oak wood is given in Fig. 3.

Hardness Measurement

Hardness measurements were performed according to the ASTM D2240 standard with a Shoremeter-D hardness tester to determine the mechanical properties of the paint layer. The test specimens were placed on the bench and the depth of the needles immersed on the specimen with a certain force was measured to determine the relative hardness of the specimen. The surface where the number is larger in the device display is hard, and the surfaces with fewer are harder.

Evaluation of the Data

The hardness values of the paint layers obtained from the test measurements were analyzed by applying the one-way variance analysis to determine whether there are significant effects of the layer thicknesses on the tested factors. When the effect of the number of paint layers was significant ($p<0.05$), the Duncan test was used for the comparison between the groups and homogeneity groups were formed. For statistical evaluations, IBM SPSS 20 statistical package program was used and it was determined whether the difference between Shoremeter-D hardness values in paint layers was significant according to the number of paint layers, as a result of the variance analysis.

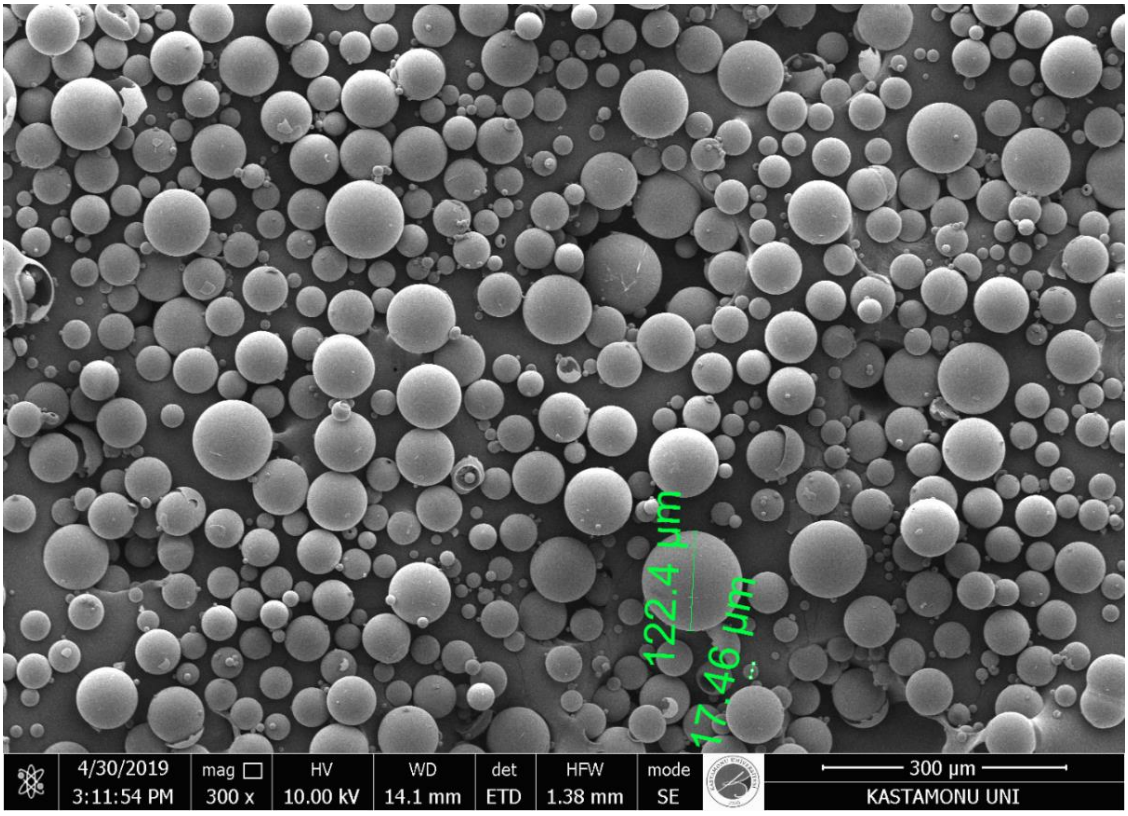

Fig. 1. SEM image of hollow glass spheres with large and small dimensions

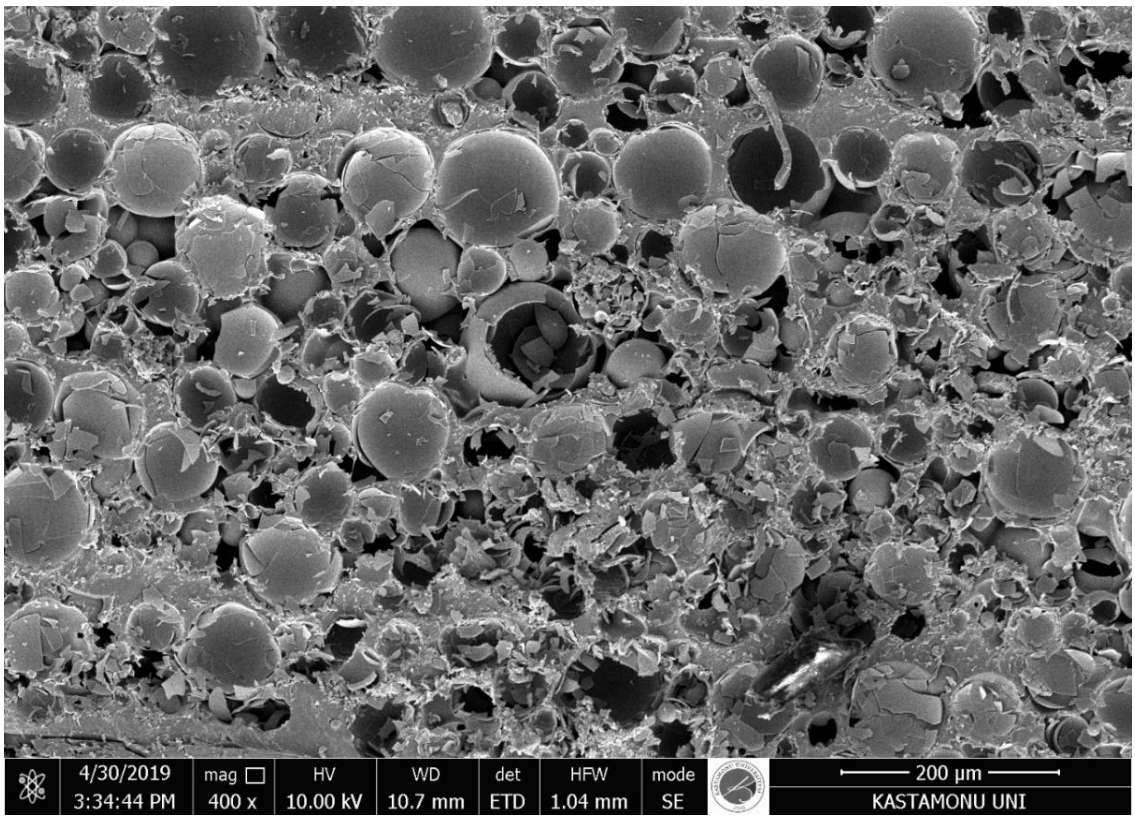

Fig. 2. SEM image of the WBPHGS applied to the test specimens

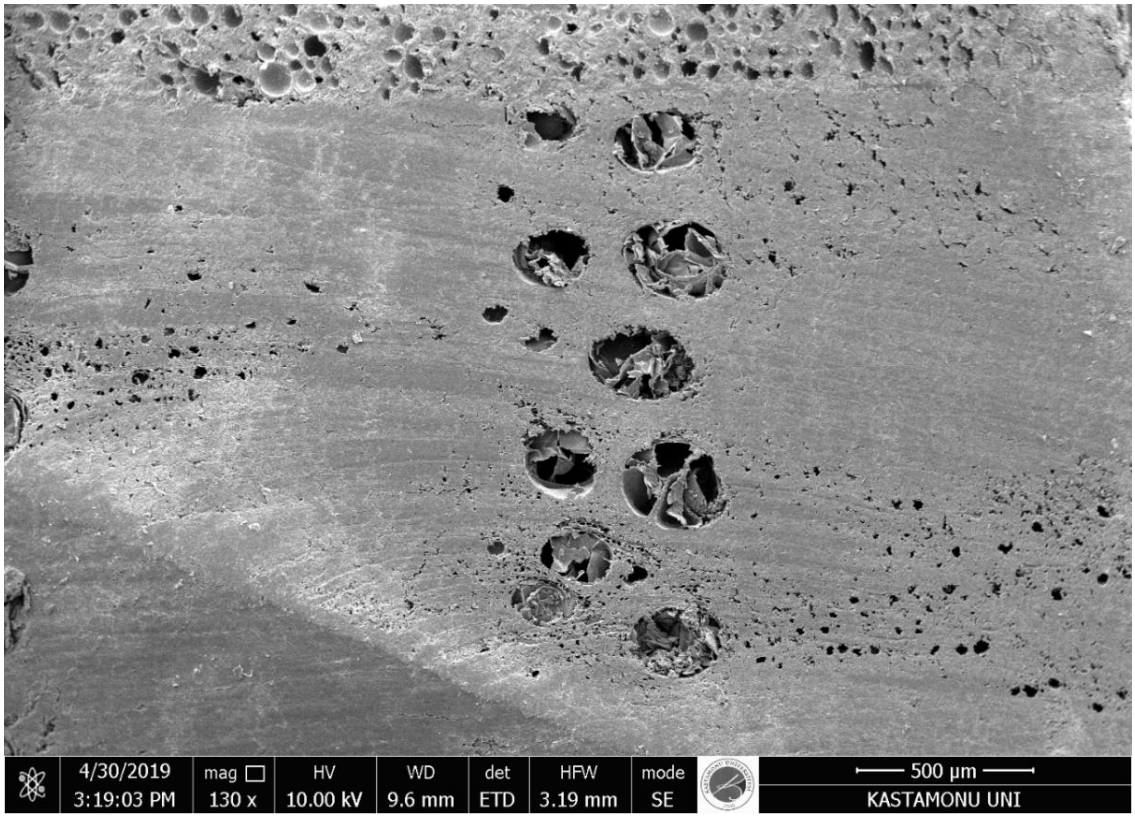

Fig. 3. SEM image of the WBPHGS on oak wood

Results and Discussion

The specimens prepared from oak woods were stored at ambient temperature of 20 ± 2 °C and 65 % ± 5 relative humidity until they reached constant weight. The weights were weighed down to a ± 0,01 g precision analytical balance and the dimensions were determined with micrometric digital calipers with ± 0,01 mm precision and the density determination was calculated according to TS ISO 13061-2. The average density value ($\bar{X}$) of the test samples was determined as 0.53 g/cm^3.

The results of the variance analysis on the hardness values of the number of paint layers are given in Table 2.

Table 2. Results of variance analysis on the effect of hardness values of layer thicknesses

	DF	Sum of Squares	Mean Square	F–Value	Probability (p<0,05)
Between Groups	3	804,917	268,306	50,695	0,000
Within Groups	92	486,917	5,293		
Total	95	1291,833			

According to Table 2, statistically significant differences were found in the hardness values of the layer thicknesses (p<0.05). The Duncan test hardness values according to layer thicknesses are given in Table 3.

Table 3. Duncan comparison test results for hardness values according to number of paint layers

Layer Thicknesses	N	Hardness values (Shormeter-D)		
		$\bar{X}$	V(%)	*HG*
Control	24	70,63	3,77	A
2 layers	24	67,71	3,50	B
4 layers	24	66,25	3,44	C
6 layers	24	62,58	2,89	D
SD± 1,37				

X: Mean value, V: Variation coefficient, HG: Homogeneous groups, SD: Significant difference

According to Table 3, the hardness value (62,58) of WBPHGS applied 6 times was found to be the lowest while the hardness value of control specimens was the highest (70,63). In a study conducted by Budakçı (1997), the hardness values varied with different thicknesses and the hardness values decrease as the layer thickness increases. Hardness, abrasion resistance and dimensional stability are important in industrial areas, but it can be said that the hardness values of WBPHGS used in the study are sufficient if soft woods can be used in houses (Kollman and Cote, 1968). In the study conducted by Saygın and Budakçı (2017), it was considered that the hardness values of some soft woods were lower than the hardness values of the current study results in the measurements made with Shoremeter hardness tester. Therefore, WBPHGS could be applied to solid wood parquet surfaces.

Conclusions and Recommendations

The hardness values of the test specimens varied according to the number of layers, the hardness values decreased as the number of layers increased and the lowest values reached the 6^{th} coat applications. If users respond positively to their needs, excessive application of layers should be avoided where high surface hardness is expected. In future studies, the color, brightness, adhesion, insulation etc. of the WBPHGS could be investigated on the solid parquet surfaces. In addition, it may be beneficial for applicators to determine the ideal hardness values of paints by different methods to determine whether they are suitable for the application. In addition, it is recommended that the paint needs to be applied as a single layer on surface to have better surface hardness which is beneficial for consumers. As a future study, it is possible to investigate the thermal insulation and adhesion resistance properties of WBPHGS applied at different layering sequences on both parquet surfaces.

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Ethics Committee Approval

N/A

Peer-review

Externally peer-reviewed.

Author Contributions

Conceptualization: H.I.K; Investigation: H.I.K., A.K.; Material and Methodology: H.I.K., A.K.; Supervision: H.I.K.; Visualization: H.I.K., A.K.; Writing-Original Draft: H.I.K.; Writing-review & Editing: H.I.K.; Other: All authors have read and agreed to the published version of manuscript.

Conflict of Interest

The authors have no conflicts of interest to declare.

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References

As, N. (1998). From the Temple of the Hebrew King Salamon to Our Halls: Parquet, Floor, Floor Covering Industry Magazine, (1), 1-4.

ASTM D 2240. (2015). *Standard Test Method for Rubber Property-Durometer Hardness.* West Conshohocken, Pennsylvania, United States.

Budakçı, M. (1997). *The effects to surface adhesion strength, hardness and brightness of layer thickness in wood varnishes*, (MSc. Thesis, Gazi University Institute of Science).

Döngel, N., Küreli, İ., & Söğütlü, C. (2008). The Effect of Dry Heat for the Colour and Gloss Changes on the Wood and Wood Based Floor Covering Materials, *Journal of Polytechnic*, 11(3), 255-263.

Kabakcı, A. (2018). *The Hardness, Adhesion and Thermal Insulation Properties of Water-Based Paint Applied as a Wood Layering Coating*, (MSc. Thesis, Kastamonu University).

Kabakcı, A., & Kesik, H. İ. (2020). The Effects of Water Based Nano Insulation Paint Applied to Laminate Flooring on Thermal Conductivity Coefficient and Adhesion Resistance,

Bioresources 15(3), 6110-6122. DOI:10.15376/biores.15.3.6110-6122.

Karamanoğlu, M., & Akyıldız, M. H. (2013). Colour, Gloss and Hardness Properties of Heat Treated Wood Exposed to Accelerated Weathering, *Pro Ligno*, ISSN-L:1841-4737, 9(4), 729-738.

Kimetsan Technical Bulletin (2018). *Kimetsan Water Based Nano Insulation Coating*, Ankara.

Kollman, F. F. P., & Cote, Jr. W. A. (1968). *Principles of wood science and technology*. I. Solid wood. Springer- Verlag New York Inc.

Kurtoğlu, A., & Ünlügil, H. (1991). Surface Treatment in Parquet. *Istanbul University Journal of Forestry Faculty*, 41(3-4), 39-46.

Özen, R., & Sönmez, A. (1999). Effect of Exterior Exposure on the Hadrness of Varnishes Coating, *Tr. J. of Agriculture and Forestry*, 23, 323–328.

Posmyk, A. (2016). Composite coatings with ceramic microspheres as ınsulating materials for transport means. *Polish Society of Composite Materials*, 16(4), 212-217.

Saygın, E., & Budakçı, M. (2017). The Effect of Resin Cleaning Process on The Hardness Value of Water-Based Varnishes. *Duzce Üniversity Journal of Science and Technology*, 5(1), 169-183.

Sönmez, A., & Budakçı, M. (2004). *Protective Layers and Paint/Varnish Systems, Finishing on Woodworking II*, Gazi University Technical Education Faculty, Sevgi Ofset, 34-48.

Tekin, A. (2009). *Determination of Abrasion Resistance of Some Varnish Layers Used on the Wood Materials*, (M.Sc., Gazi University Science Institution).

TS ISO 3129. (2021). *Wood - Sampling Methods and General Requirements for Physical and Mechanical Tests*, TSE, Ankara.

TS ISO 13061-1. (2021). *Wood, Determination of Moisture Content for Physical and Mechanical Test*, TSE, Ankara.

TS ISO 13061-2. (2021). *Wood - Determination of Density for Physical and Mechanical Tests*, TSE, Ankara.

Wang, F., Liang, J., Tang, Q., Chen, C., & Chen, Y. (2014). Preparation and performance of thermal insulation energy saving coating materials for exterior wall. *Journal of Nanoscience and Nanotechnology*, 14(5), 3861–3867. DOI: 10.1166/jnn.2014.8034.