

Effects of Japanese Wood Burning Technique (Shou Sugi Ban) on Hardness and Surface Roughness of Cellulosic Varnish

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Abstract

This study aims to determine the effect of Shou Sugi Ban (SSB) on hardness and surface roughness of cellulosic varnish. For this purpose, the wood surfaces of Scots pine (*Pinus sylvestris* Lipsky) were burned with a blowtorch at about 15- to 20-cm distance and 3- to 5-mm depth, until the surface turned into a charcoal color. The burned surfaces were cleaned based on the technique and cellulosic varnish was applied. Hardness of the varnish layer was determined according to ASTM D4366-16 and surface roughness TS 6956 EN ISO 4287/A1 principles. Results showed that the SSB burning technique increased the hardness and surface roughness values of the cellulosic varnish layers than the control.

Keywords: *Wood burning, Shou Sugi Ban, Hardness, Surface roughness, Cellulosic Varnish*

I. INTRODUCTION

Wood materials are widely used for building materials and interior designs [1,2,3] resulting in the increasing global demands and growing environmental concerns [1]. However, unprotected or untreated wood materials can be easily degraded under direct exposure to humidity and other suitable conditions favorable for the attack of biological organisms such as fungi, molds and insects. Similarly, long exposure of the wood to sunlight, temperature gradients, chemicals, wind, and rain also results in degradation, aging, and deterioration of quality, which are

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considered to be the biggest setback of wood products. For these reasons, wood protection against these degradation agents is necessary to preserve wood quality and strengthen the lifespan and serviceability of wood products, which is usually done through wood treatments using heat, chemicals, and other surface treatment techniques [4,5,6,7,8,9,10,11].

One of the types of heat treatment is burning, which is an ancient technique to protect wood material. In Japan, one of the famous burning techniques is known as the "Shou Sugi Ban (SSB)", "sugi ban" or "yakisugi", which is an ancient Japanese surface finishing technique originated from the Edo region since 1600s to mitigate the occurrence of fires particularly in urban areas. The SSB is a natural and environmentally friendly wood preservation technique, which results in increased resistance of wood surface against biological pests, water, moisture and fire due to the formation of a black and charred layer and carbonized the surface of the wood [3,12,13,14]. The employment of the SSB technique has already gained worldwide popularity as manifested by the employment of this wood protection technique in many different surface finishing processes (coloring, varnishing or a combination of both, etc.), both in indoor and outdoor wood products [3]. This study aims to investigate the effects of SSB on hardness and surface roughness of cellulosic varnish.

II. MATERIALS AND METHODS

Preparation of Wood Samples

Woods (4-5 cm x 12-14 cm x 300-320 cm) of Scotch pine (*Pinus sylvestris* L.) were randomly selected from mixed heartwood and sapwood of good quality (smooth fibers, no knots, no cracks, no difference in color and density, and annual rings perpendicular), and then kiln dried to constant weight [15].. A varnish, which is composed of an alkyd resin-based nitrocellulose modified one-component filler and topcoat varnishes were used, which technical descriptions are summarized below (Table 1).

Table 1. Chemical and Physical Characteristics of the Varnishes.

Varnishes	Chemical and physical characteristics			
	Density (g/cm ³)	Viscosity (sn./DIN Cup 4mm/20 °C)	Solid Material Percentage (%)	Application Amount (g/m ²)
Filler	0.95	14	30	220
Top Coat	1	16	32.5	160

The wood samples were cut into pieces with dimensions of 320 mm x 90 mm x 15 mm . The fiber direction parallel to the length axis and annual rings perpendicular to the wide surfaces. The samples were climatized according to TS 642 ISO 554 [16]. After climatization, the samples were further cut into smaller dimensions of 100 mm x 75 mm x 10 mm. The samples were smoothed using 80, 100 and 220 grit sandpaper, respectively. Then, fiber embossing process was applied to the samples and sanded again with 220 grit sandpaper. All sandpapers, which are waterproof silicon carbide papers, were attached to the rotating head of hand sanding machine.

Heating Treatment and Varnish Application

The Shou Sugi Ban (SSB) burning technique was applied using a blowtorch (Figure 1 and Figure 2), which is a modified approach of the traditional application method (creating a triangular pyramid from wood, wrapping with rope and burning through the pyramid) [3]. The burning process was done slowly until they were totally charred to a depth of 3- to 5-mm at a distance of 15- to 20-cm (Figure 3). Then, the samples were allowed to cool for 24 hours (Figure 4). Prior to the application of varnish, ashes and other impurities were removed using an iron wire brush and blown by an air compressor (Figure 5). Then, the sample surfaces were lightly sanded with 320 grit sandpaper. Cleaning with a wire brush was carried out in the direction of the fiber.

The varnish was applied to the wood samples using a brush following the manufacturer's recommendations and ASTM



Figure 1. Traditional Wood Burning Technique [12].

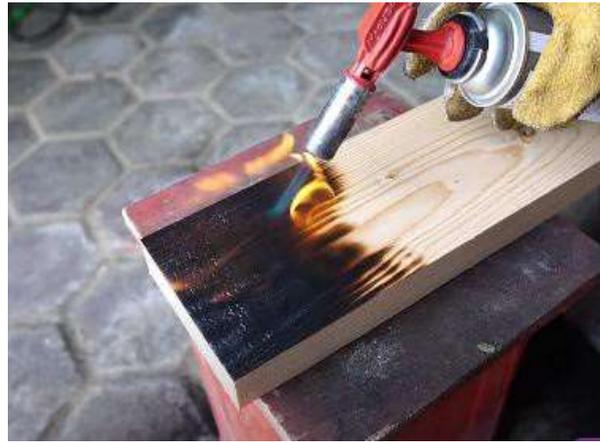


Figure 2. Alternative to Traditional Technique - Burn Process with a Blowtorch [3].

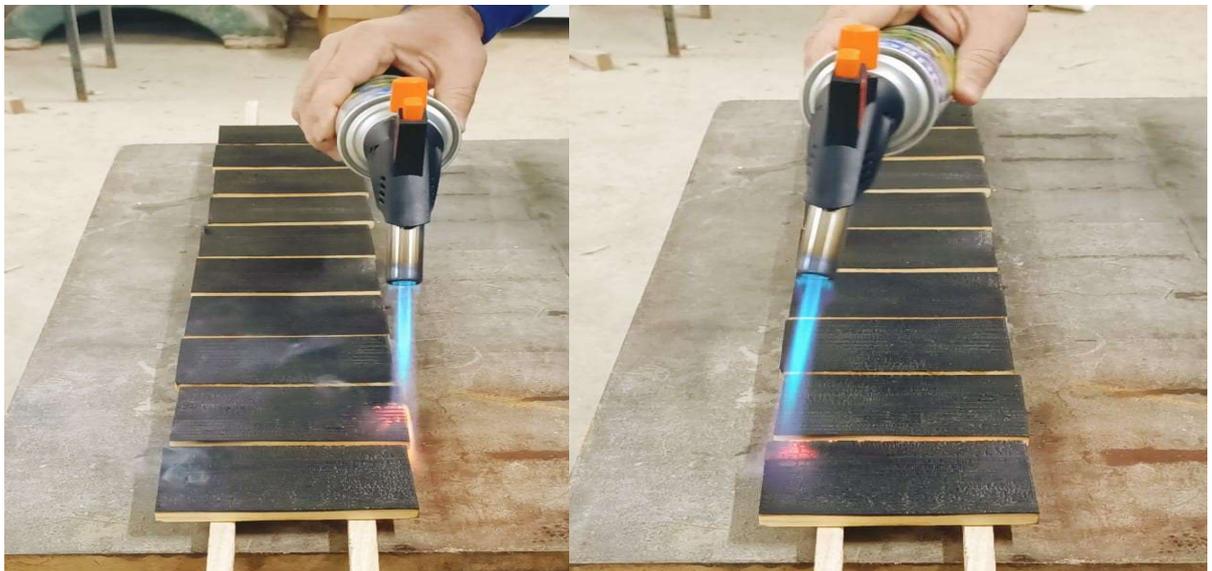


Figure 3. Burning Samples with a Blowtorch



Figure 4. Control and Burned Samples



Figure 5. Ash and Char Layer Cleaned Samples

D3023-98 principles [17]. After varnishing with filler varnish (1 cross coat), the samples were sanded lightly with 600 grit sandpaper. Then, the top coat (2 cross coats) of varnish was applied, and then waited for 1 hour between the top coats in line with the company's directives. The varnished samples were cleaned of dust and dried at room temperature in a position parallel to the ground plane.

Hardness (Pendulum Damping) Measurement

The hardness of wood samples were measured with the Onalxon BGD509 pendulum hardness measuring device according to the Köning method (from 6° to 3°) [18]. Measurements were made in the direction parallel to the fibers and without distinction between earlywood and latewood. The layer hardness was determined based on the swings of the pendulum over the sample surfaces on the measuring platform. Surfaces with more swings mean harder than surfaces with less swings.

Surface Roughness Measurement

Surface roughness measurements of the samples were made with Accretech Handysurf E-35 B (Tokyo Seimitsu) needle scanning surface roughness measuring device according to TS 6956 EN ISO 4287/A1 principles [19]. Measurements were made at room temperature, away from vibration and noise sources with a 5 µm tip diameter, a 0.5 mm sec⁻¹ measuring speed, a 12.5 mm sampling length, and a $\lambda_c = 2.5$ mm cut-off length. The device was calibrated before the measurements. The roughness measurement was made in the direction perpendicular to the fibers. The average surface roughness (*Ra*) and ten point average surface roughness (*Rz*) values of the samples were also determined.

III. RESULTS AND DISCUSSION

Results

The SSB burning technique increased the hardness and surface roughness values of the cellulosic varnish layers compared

to the control. Results of the tests of hardness and surface roughness with cellulosic varnish applied to the control and burning technique (SSB) samples is summarized below (Table 2).

Table 2. Results of the Hardness and Surface Roughness Values of the Varnish Layer.

Tests	Samples	\bar{x}	Sd	Xmin	Xmax
Hardness	Control	54.50	1.90	51.00	57.00
	SSB	64.50	3.37	59.00	70.00
Surface Roughness (<i>Ra</i>)	Control	1.38	0.25	1.04	1.80
	SSB	17.79	2.47	15.10	21.00
Surface Roughness (<i>Rz</i>)	Control	7.51	1.38	5.12	9.11
	SSB	73.88	8.63	62.60	86.40

\bar{x} : arithmetic mean Sd: standard deviation

Discussion

The increased hardness and roughness of wood samples in which the SSB were applied could be attributed the formation of the protective and durable layer due to the removal of surface carbohydrates, formation of a hydrophobic char layer, and infusion of smoke into the inner layer of the wood. The burning of the surface caused the degradation of the first few millimeters of combustible materials such as lignin, cellulose and hemicellulose and other wood chemical components [3,12,13,14].. Thus, the application of SSB resulted in the formation of hydrophobic and stable surface structure, which made it durable and care-free option against photodegradation, water, fire, fungi and insects.

Also, the uneven or corrugated wood surface following the cleaning of the burned surface or charred layer could be related to the different rates of burning resistance of the different wood layers in which it is thought that early wood burned rapidly than latewood. The higher hardness and surface roughness values of the burned and varnished samples than the control samples could also be explained by formation corrugated surface, which affects

the layer hardness and surface roughness of the cellulosic varnish being applied to the wood surfaces, which probably explains.

IV. CONCLUSION AND RECOMMENDATIONS

Although the SSB is essentially a technique applied to protect the wood against outdoor conditions, it is also widely used in the production of aesthetic and rustic works in interior and exterior decoration today. It is thought that the type selected material (softwood or hardwood) and the burning application parameters (exposure time, distance, depth, etc.) would introduce different effects on the varnish layer performance of SSB. Since application method of the SSB is not yet standardized, it is expected that the burning time and depth, cleaning method and materials used (sandpaper, wire brush, etc.) and the operator factors will generate different results in the layer performance of the wood texture structure. The SSB increased the hardness and surface roughness of the cellulosic varnish layer. Thus, it is important to apply SSB, which is a wood protection method, to different materials with different parameters and to investigate its effect on different surface finishing processes and performances. In the application of SSB, it is recommended that the application should be evenly applied over the entire surface of the wood as a way to ensure effectiveness of its application and production of homogenous charred surface. This study will guide the operators in the sector and the academic studies to be done.

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