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GÖKAY NEMLİ

HÜLYA KALAYCIOĞLU

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Effects of Surface Coating Materials on the Thermal Conductivity and Combustion Properties of Particleboard*

Gökay NEMLİ, Hülya KALAYCIOĞLU
Karadeniz Technical University, Faculty of Forestry, Trabzon - TURKEY

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Abstract: The specific properties of particleboard samples used in this study were as follows: 280x210x1.8 cm dimensions, 0.68 g/cm^3 specific gravity. Produced boards were coated with lacquered paint, melamine impregnated papers, wood veneers and continue press laminates. The effects of surface coating material type, melamine paper weight, wood veneer type and thickness, and continue press laminate thickness on the thermal conductivity and combustion properties of particleboard were investigated. Results showed that surface coating material type was found to affect these properties. Melamine paper weight and wood veneer thickness did not affect the thermal conductivity and combustion properties of particleboard samples. Wood veneer type and continue press laminate thickness affected these properties. Surface coating materials increased the thermal conductivity. Coated particleboard was more combustible than uncoated particleboard. Additional work is needed to improve the fire retardancy properties of these materials. A standard including the thermal conductivity values of coated and uncoated particleboard should be prepared.

Key Words: Particleboard, melamine paper, lacquered paint, wood veneer, continue press laminate, thermal conductivity, combustion properties.

Yüzey Kaplama Malzemelerinin Yongalevhaların Isı İletkenliği ve Yanma Özellikleri Üzerine Etkileri

Özet: Bu çalışmada 280x210x1.8 cm boyutlarında, 0.68 g/cm^3 yoğunlukta yongalevhalar üretilmiştir. Üretilen yongalevhalar lake boya, melamin emdirilmiş kağıtlar, ahşap kaplama levhaları ve rulo laminatları ile kaplanmıştır. Yüzey kaplama malzemesi çeşidi, melamin kağıt gramajı, ahşap kaplama çeşit ve kalınlığı ile rulo laminatıkalınlığının yongalevhalarda ısı iletkenliği ve yanma özellikleri üzerine etkileri araştırılmıştır. Yapılan çalışmalar sonucu; ısı iletkenliği ve yanma özellikleri üzerinde yüzey kaplama malzemesi ve ahşap kaplama çeşidi ile rulo laminatı kalınlığının etkili, melamin kağıt gramajı ve ahşap kaplama kalınlığının ise etkisiz olduğu belirlenmiştir. Yüzey kaplama malzemeleri ısı iletkenliğini arttırmıştır. Kaplanmış yongalevhaların kaplanmamış levhalara göre daha yanıcı özellik taşıdığı belirlenmiştir. Bu malzemelerin yanma özelliklerini iyileştirici ek bir çalışmaya ihtiyaç vardır. Yongalevhaların sahip olması gereken ısı iletkenliği konusunda bir standart hazırlanmalıdır.

Anahtar Sözcükler: Yongalevha, melamin emdirilmiş kağıt, lake boya, ahşap kaplama, rulo laminatı, ısı iletkenliği, yanma özellikleri

Introduction

Over the past several years, industrial grade particleboard has been recognized throughout the wood industry as an ideal substrate for laminated panel constructions, utilizing various types of overlay surfacing materials. Particleboard is favored by the laminate industry because of its uniform density, thickness tolerance and surface smoothness. Other board properties, such as dimensional stability, strength, stiffness, flatness, and workability, contribute significantly to the ease of fabrication and ultimate performance of the laminated end product. High pressure laminates, low pressure, resin saturated papers, vinyl films, hot transfer films, decorative papers, lacquered paint and wood veneers comprise the types of overlay materials most commonly applied to particleboard substrates (Bohme, 1971; Akbulut and Dündar, 1994; Currier, 1977; Kolmann, 1966).

There exists no information about the effects of surface coating materials on the thermal conductivity and combustion properties of particleboards. Research has been carried out on the effects of surface coating materials on the physical, mechanical properties and formaldehyde emission of particleboard. According to

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Chow et al. (1996), wood veneer coating did not affect internal bonding but did increase the bending strength. As reported by Niazi and Gertjojensen (1979), aspen venered particleboard had more linear dimensional stability than uncoated particleboard. Groah et al. (1984) stated that decorative vinyl overlay decreased the formaldehyde emission of particleboard. According to Grigoriou (1987), the coating of particleboard surfaces with melamine impregnated paper and wood veneer decreased formaldehyde emissions. Nemli (2000) stated that surface coating materials improved the physical and mechanical properties of particleboard.

Wood and wood-based materials consist of organic compounds that are composed mainly of carbon and hydrogen, and for this reason they are combustible (Kollmann and Cöte, 1968). The combustibility of the wood is favorable when it is used as a fuel, but unfavorable as a building material. When wood burns, it undergoes thermal decomposition (pyrolysis) and yields volatile products of lower molecular weight. These volatiles react with atmospheric oxygen in the gas phase; this is the combustion stage and is accompannied by flame (Nassar et al., 1986). Martin (1965) and Shafizadeh et al. (1982) proposed that there are at least two competitive reactions by which wood decomposes thermally. The primary reaction produces mainly water, char and oxides of carbon; a secondary reaction supplies the bulk of the volatile fuels.

Coated particleboard applications are table tops, kitchen and office furniture, cabinets, interior signs and displays, underlayment as flooring, isolation board, sliding and flush doors, and lock blocks. For this reason, thermal conductivity and combustion properties are very important for particleboard and its end use.

Research has not been carried out on the effects of surface coating materials on the thermal conductivity and combustion propereties of particleboard. The objective of this work was to evaluate the thermal conductivity and combustion performance of particleboard samples.

Materials and Methods

In the production of particleboards samples; beech (50%), pine (40%) and poplar (10%) woods were used. A hacker was used to initially break the woods down, then a Palmann flaker was used to reduce hacker chips to particles. After these processes, the particles were dried to 3% moisture content and seperated by a vibrating horizontal screen. For the blending an adhesive urea formaldehyde 8% and 11% of the oven dry weight of particles in the core and face layers, was used. As a hardener, 30% of ammonium chloride solution was used and as a hydrophobic substance 32% of paraffin solution was added. The solid content of urea formaldehyde was 60%. The boards were pressed at 225°C for 110 sec at 3.5 N/mm^2. After pressing, the boards were conditioned to constant mass at 65±5% relative humidity and at a temperature of 20±2°C. The following surface coating materials were used on the particleboard samples:

1. Lacquered Paint

First Step: Lacquer filler (polyurethane based, solid content 70%) was spread over about 170 g/m^2

Second Step: Wash coat (polyurethane based, solid content 74%) was spread over about 170 g/m^2

Third Step: Lacquer paint (polyurethane based, solid content 51%) was spread over about 170 g/m^2

2. Melamine Impregnated Papers

a. Weight 80 g/m^2, white

b. Weight 90 g/m^2, black

Melamine impregnated papers were pressed particleboard surfaces at 190°C for 25 sec. and at 2.6 N/mm2. In the production of melamine paper, alpha cellulose based papers were impregnated with melamine + urea formaldehyde resin of about 56%.

3. Wood Veneers

a. Okoume wood veneer, 0.55 and 0.65 mm thicknesses

b. Bubinga wood veneer, 0.55 and 0.70 mm thicknesses

After coating the particleboard with wood veneers, the surfaces were coated with polyurethane based paint, filler and top coat polish, respectively.

4. Continue Press Laminates (CPL)

a. 0.55 mm thickness

b. 0.70 mm thickness

Continue press laminates and wood veneers were pressed onto the particleboard surfaces at 90°C for 4 min and at 0.15 N/mm^2. Enpostform HV adhesive having 53% solid content was used for coating the board surfaces with continue press laminates and wood veneers. The structure of continue press laminates are shown in Figures 1 and 2.

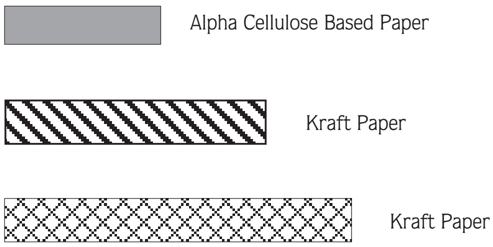

Figure 1. The structure of 0.55 mm thickness continue press laminate.

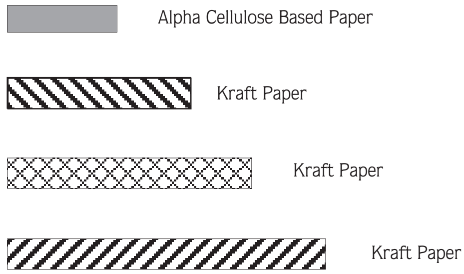

Figure 2. The structure of 0.70 mm thickness continue press laminate.

In the production of continue press laminates, alpha cellulose based paper and kraft papers were impregnated with melamine formaldehyde and phenol formaldehyde resins of about 56% and 46%, respectively. The layers were pressed at 220°C for 35 sec and at 2.5 N/mm^2 pressure. Table 1 shows the experimental design of the study.

Specific gravity, thermal conductivity and combustion properties tests were conducted according to the TS EN 323/1 (1999), TS 388 (1977) and ASTM E 160-50 (1975) standards, respectively. For the specific gravity testing 30 specimens were used, and for the thermal conductivity testing three specimens were prepared randomly. Twenty-four specimens and three replicates of each variation were used for combustion testing. Data for each test were statistically analyzed. F-tests were used (alpha = 0.05) to test for significant differences between factors and levels. When the F-test indicated a significant difference among factors and levels, a simple comparison of means was done employing a Duncan test to identify which groups were significantly different.

Table 1. Experimental design.

Particleboard Type	Surface Coating Material Type	Weight (g/m^2)	Thickness (mm)
K*	-	-	-
L	Lacquered Paint	-	-
M80	Melamine Impregnated Paper	80	-
M90	Melamine Impregnated Paper	90	-
O1	Okoume Wood Veneer	-	0.55
O2	Okoume Wood Veneer	-	0.65
B1	Bubinga Wood Veneer	-	0.55
B2	Bubinga Wood Veneer	-	0.65
CPL1	CPL	-	0.55
CPL2	CPL	-	0.70

* Uncoated particleboard

Results and Discussion

Values for average specific gravity, thermal conductivity and combustion properties of particleboards and the statistical analysis results are shown in Tables 2 and 3.

According to the simple variation analysis results, surface coating materials affected specific gravity, thermal conductivity and combustion properties. Simple variation analysis indicated a significant difference between factors and levels, and a simple comparison of the means was done employing a Duncan test to identify which groups were significantly different. Duncan tests showed that melamine paper weight and wood veneer thickness did not affect the properties of particleboards. Surface coating material type, wood veneer type and continue press laminate thickness were found to influence these properties.

Coating particleboard surfaces with lacquered paint increased the thermal conductivity, combustion temperature and weight loss, though decreased the combustion time. This may be due to the increase in the

Table 2. Values for average specific gravity and thermal conductivity and the statistical analysis results.

Particleboard Type	Specific Gravity* (g /cm^3)	Thermal Conductivity** (kcal / mh°C)
K	0.666 a	0.0916 a
L	0.685 b	0.0946 b
M80	0.700 c	0.0976 c
M90	0.703 c	0.0980 c
O1	0.717 d	0.1016 d
O2	0.719 d	0.1020 d
B1	0.730 e	0.1063 e
B2	0.733 e	0.1066 e
CPL1	0.745 f	0.1106 f
CPL2	0.760 g	0.1153 g

Note: *-p < 0.01, **- p < 0.1

Table 3. Values for average combustion properties of particleboard samples and the statistical analysis results.

Types	THS ˚C*	TWHS sec*	twhs ˚C*	TG sec*	tg ˚C*	DT sec.*	WL %*
K	176.21 a	805.33 a	298.01 a	937.66 a	131.60 a	1627.00 a	92.25 a
L	193.39 b	715.00 b	317.80 b	851.66 b	151.39 b	1490.00 b	92.92 b
M80	220.56 c	602.33 c	380.53 c	612.33 c	173.96 c	1035.33 c	93.87 c
M90	220.72 c	611.66 c	381.92 c	615.66 c	174.40 c	1040.33 c	93.80 c
O1	243.39 d	479.00 d	420.87 d	413.66 d	197.72 d	874.00 d	94.66 d
O2	247.73 d	481.33 d	423.25 d	417.33 d	198.54 d	877.33 d	94.62 d
B1	259.54 e	542.00 e	476.00 e	508.66 e	215.78 e	952.66 e	94.25 e
B2	261.53 e	549.33 e	280.42 e	510.00 e	218.51 e	956.33 e	94.21 e
CPL1	277.10 f	394.33 f	524.24 f	374.00 f	228.71 f	777.33 f	95.14 f
CPL2	298.11 g	345.66 g	588.29 g	210.66 g	206.07 g	634.33 g	95.64 g

Note: THS- Temperature value with heat sources, TWHS- Time value without heat source, twhs- Temperature value without heat source, TG- Time value after glow, tg- Temperature value after glow, DT- Destruction time, WL- Weight loss, *- $p < 0.01$

particleboard's specific gravity after the application of lacquered paint. Bozkurt and Göker (1985) stated that increasing particleboard specific gravity resulted in an increase in thermal conductivity. Lacquered paint is polyurethane based and has combustible properties. For this reason, coating particleboard surfaces with lacquered paint increased the combustion temperature and decreased the combustion time.

Coated particleboard samples with melamine impregnated papers had higher thermal conductivity, combustion temperature, weight loss and lower combustion time than lacquered paint coated and uncoated particleboard samples. This may be due to increase in board specific gravity by melamine impregnated papers and the use of melamine + urea formaldehyde resin on the melamine paper. According to Berkel (1972), the application of synthetic resin increased the thermal conductivity of wood. It is known that synthetic resins have combustible properties. For this reason, combustion temperatures increased and combustion times decreased. Melamine paper weight did not affect the thermal conductivity or combustion properties. This may be due to the small difference between the melamine paper weights and the same ratio and resin formulation impregnated onto the alpha cellulose based paper. According to the results of this study, melamine paper weight had no effect on the specific gravity.

Wood veneer coating increased the thermal conductivity, combustion temperature and weight loss, though decreased the combustion time of particleboard. This may be due to an increase particleboard specific gravity. According to Bozkurt and Göker (1987), ligno cellulosic materials contain pores. For this reason, they have lower thermal conductivity than other materials. In the production of veneer coated particleboard, veneer surfaces were coated with polyurethane based paint, filler and top coat polish, while an adhesive was used on the particleboard surfaces. For this reason, face layers are compact and these materials have combustible properties. Wood veneer type was found to have an effect on the thermal conductivity and combustion properties of particleboard. Bubinga coated particleboards had higher thermal conductivity, combustion temperature, combustion time and lower weight loss than okoume coated boards. This may be due to specific gravity differences in the wood veneers. Bubinga wood veneer had higher specific gravity than okoume veneer. Wood veneer thickness did not affect the thermal conductivity and combustion properties. This may be due to the small difference between the veneer thicknesses. In this study, it was found that wood veneer thickness did not affect the specific gravity. The same results were found by Chow and Redmond (1981). They reported that increasing wood veneer thickness from 0.21 mm to 0.31 mm did not affect the strength properties of particleboard.

Coating of particleboard surfaces with continue press laminate increased thehermal conductivity, combustion temperature and weight loss, decreased the combustion time. The coating of particleboard surfaces with continue press laminate caused an increase in the specific gravity of the board. In addition, melamine and phenol formaldehyde resin, which have combustible properties, were used in the production of continue press laminate. For these reasons, combustion temperature increased and combustion time decreased. When the particleboard surfaces were coated with continue press laminate, the surfaces became compact. The compact structure of the surfaces caused an increase in thermal conductivity. Increasing continue press laminate thickness from 0.55 mm to 0.70 mm resulted in an increase in thermal conductivity, combustion time and weight loss, and a decrease in combustion time. This may be due to the increasi in specific gravity. Two kraft papers were used in the production of 0.55 mm thickness continue press laminate. However, for 0.70 mm thickness continue press laminate, three kraft papers impregnated with phenol formaldehyde resin were used.

Surface coating material type was found to affect thermal conductivity and combustion properties. The highest and the lowest values were obtained from continue press laminate and lacquered paint coated particleboard samples, respectively.

Conclusions

The coating of particleboard surfaces with surface coating materials decreased the fire retardancy of particleboard. Additional work is needed to improve the fire retardancy properties of these materials.

Surface coating materials increased the thermal conductivity of particleboard. Coated particleboard applications are table tops, kitchen and office furniture, cabinets, interior signs and displays, flooring underlay, isolation board, sliding and flush doors, and lock blocks.

For the flooring underlay, isolation board or door applications, particleboards that have low thermal conductivity should be chosen. But for table tops, kitchen or office furniture applications, particleboards which have high thermal conductivity should be used.

For kitchen furniture applications, the coated particleboard must be resistant to boiling water, dry heat and cigarette burns. Any increase in thermal conductivity will result in the transfer of heat from the surface layer to the other layers. For this reason, any impact will be decreased on the surface. As a result, coated particleboard will be resistant to boiling water, dry heat and cigarette burns.

In addition, a standard including the thermal conductivity values of coated and uncoated particleboard should be prepared. The solvent effects of liquids on these materials should be investigated.

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