J. Korean Wood Sci. Technol. 2016, 44(4): 600~606
pISSN: 1017-0715 eISSN: 2233-7180
http://dx.doi.org/DOI:10.5658/WOOD.2016.44.4.600

Original Article

Formaldehyde Emission of Wood-Based Composite Panels with Different Surface Lamination Materials Using Desiccator Method[1]

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ABSTRACT

Wood-based composite panels such as plywood, particleboard (PB), or medium density fiberboard (MDF) are mostly used in the lamination on their surface for the manufacturing of furniture, or interior building products, the concern on the formaldehyde emission (FE) from the surface laminated wood panels is increasingly attracting attentions from the public. Thus, this study was conducted to understand influence of surface laminating materials to the FE from PB and MDF with or without edge sealing, using 24-hour desiccator method. Both PB samples that had been laminated on their surface with low-pressure laminate (LPL) or polypropylene (PP) film and MDF that had been treated with poly(vinyl chloride) (PVC) or coating were tested for the FE with or without edge sealing. As expected, the FE of PB with the sealed edges decreased to 37.4% and 80.7% with the LPL and PP lamination, respectively. The surface laminated MDF with the sealed edges also showed a decrease in the emission up to 57.8% and 54.3%, with the PVC lamination and coating, respectively. However, the coated MDF samples showed 5.3% increase in the emission when their edges were not sealed, indicating a FE form the solvent used for coating. These results showed that the type of surface lamination materials on wood-based composite panels has a great impact on their resultant FE, indicating that the influence of surface laminating materials should be taken into consideration for the formaldehyde mission measurement.

Keywords: formaldehyde emission, wood-based composites, surface lamination, edge sealing

1. INTRODUCTION

Various reconstituted wood panel products such as plywood, particleboard (PB), medium density fiberboard (MDF), and so on have become increasingly popular, and are being used for manufacturing furniture, cabinets, or building products. These products are mainly being bonded with formaldehyde-based resins such as urea-formaldehyde (UF) resin, melamine-urea-formaldehyde (MUF) resin, phenol-formaldehyde (PF) resins, etc.

Compared to other wood adhesives, such as PF resins and polymeric diphenylmethane diiso-

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cyanate (pMDI), UF resin possesses some advantages such as fast curing, good performance in the panel, water solubility and lower price. Disadvantages of using the UF resin are lower resistance to water and its formaldehyde emission (FE) from the panels. Lower resistance to water limits UF resin-bonded panels to interior applications. FE issue was one of the most important aspects of UF resin in last few decades (Myers, 1987; Myers, 1986; Pizzi, 1994). The reversibility of the aminomethylene link and hence the susceptibility to hydrolysis explains lower resistance against the influences of water and moisture, and subsequently FE (Baumann *et al*., 2000). Thus, the use of UF resin bonded wood-based composite panels is limited only to non-structural applications due to the lack of water resistance.

The FE of wood-based panel products has been received a great attention from public as well as wood industries since formaldehyde was known as a toxic air contaminant, and carcinogen since a German teacher firstly reported the problem of FE in 1973 (Deimel, 1978). FE was one of the most important aspects of UF resin in last few decades (Myers and Hermanns, 1985; Marutzky, 1989). Amino resins such as UF resin or MUF resin are mainly responsible for the FE when they were used as a binder for wood-based composite panels. Many authors published excellent reviews on this matter (Meyer and Hermanns, 1986; Meyers, 1984). The reversibility of the cross-linking in cured UF resins under moisture and high temperature results in their hydrolysis which consequently causes lower water resistance, and subsequent FE (Dunky, 1998). Thus, wood-based composite panels manufactured with UF resins are limited to non-structural applications.

In addition, an effort to reduce energy losses in house after the energy crisis in 1970's subsequently resulted in an increase of air tightness of indoor environment, which accelerated the FE problem. In 1980's, the first guideline for FE was adopted in Germany (Marutzky and Margosian, 1995). There are many factors affecting the FE of wood panel products (Marutzky, 1989). Thus, much attention has been paid to reduce or control the FE from UF resin-bonded panels. The presence of free formaldehyde in the UF resins prepared is one of the reasons for FE (Park *et al*., 2006). One of the approaches of reducing FE was to lower F/U molar ratio of the synthesized resin (Park *et al*., 2007). However, lower F/U molar ratio reduced FE at the expense of poor mechanical properties such as internal bond (IB) strength and modulus of rupture (MOR) (Myers, 1984).

In practice, wood-based composite panels are being used for fabricating many products after their surface lamination with various synthetic polymer films such as low-pressure laminate (LPL), poly(vinyl chloride) (PVC) film, and polypropylene (PP) film. However, the influence of these surface laminating materials to the FE was not studied. Thus, the purpose of this work is to investigate the influence of surface laminating material types of wood-based composite panels on their FE, using 24-hour desiccator method.

Table 1. Panel type, surface laminating material type, and the number of specimens used

Panel type	Surface laminating material type	Panel thickness (mm)	Number of specimens per replication	Total number of specimens
PB	Control	18	8	24
	LPL	18	8	24
	PP*	15	9	27
MDF	Control	18	8	24
	PVC	18	8	24
	Coating	18	8	24

* The formaldehyde emission was normalized by the total surface area of sample of 18 mm thickness.

2. MATERIALS and METHODS

2.1. Materials

General grade PB or MDF of 18 mm thick from a commercial furniture manufacturing company in Republic of Korea were used in this study. Each panel type was laminated on their surface with different types of laminating materials. Types of surface laminating materials and the number of samples of both PB and MDF samples were presented in Table 1. The surfaces of PB samples were laminated either with low pressure laminate (LPL) that had been impregnated by melamine formaldehyde (MF) resin or with polypropylene (PP) film bonded by a solvent-based adhesive. The MDF surfaces were laminated either with poly(vinyl chloride) (PVC) film bonded by a solvent-based adhesive or with coating cured by ultraviolet radiation.

Dimensions of the samples were 50 cm × 50 cm. These samples were warped with three polyethylene bags at the time of collection. Prior to conducting of measuring FE, these samples were cut into three sets of specimens with 5 cm × 15 cm dimension for the desiccator method. The number of specimens was adjusted to meet the total surface area of 1800 cm^2.

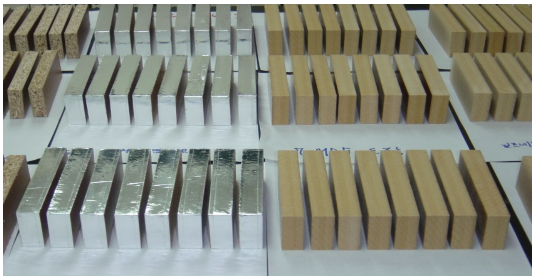

Fig. 1. An image of MDF specimens with the un-sealed and sealed edges.

All four edges of the specimens were sealed with aluminum double tape in order to investigate the influence of edge sealing to the FE from PB and MDF. Fig. 1 shows an image of the specimen with edges of un-sealed and sealed states of MDF.

2.2. Methods

All PB and MDF panels with different types of surface lamination materials were cut into test specimens with 5 cm × 15 cm dimensions according to the procedure specified in the Korea Standards (KS F 3104, 2009 and F 3200,

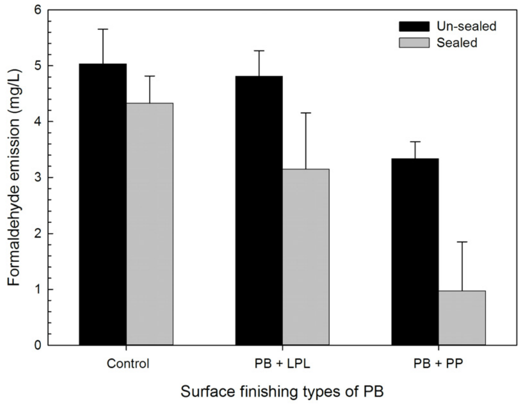

Fig. 2. FEs of PB with different laminating material types and sealing states.

2009). These specimens were conditioned for seven days at 20℃ and 65% relative humidity to eliminate any experimental errors. After conditioning, test specimens were put in a glass desiccator with 240 mm inside diameter, containing 300 mℓ distilled water for 24 hours. The concentration of FE of each sample was determined by the acetyl-acetone method at 412 nm of UV spectrophotometer. The formaldehyde concentrations determined were corrected by the ratio of 1800 cm^2 to the total surface area of a sample as shown below in the Equation (1):

$$C_f = F \times \frac{1800\ (cm^2)}{S} \quad \text{(1)}$$

where C_f (mg/ℓ) is the FE corrected, F (mg/ℓ) the FE of desiccator method, and S the total surface area of test specimens (cm^2). An average of three determinations was reported.

3. RESULTS and DISCUSSION

Fig. 1 shows the measurement results of FE of PB and MDF with different surface laminating types of materials. Also, the results of both samples with either un-sealed or sealed edges were included. As shown Fig. 1, the FE values of the control PB was 5.036 mg/ℓ, which decreased to 4.327 mg/ℓ, and 3.3 mg/ℓ for the laminated PBs with LPL and PP, respectively, when the edges were not sealed. This might be attributed to the presence of surface laminating materials covered on the specimen, which prevented the emission of formaldehyde from the surface of PB. In addition, the FE of PB further decreased for the specimens with sealed edges. The reduction extent of FE of PB with PP lamination was much greater than those of PB laminated with LPL on the surface. As expected, these results also suggest that the surface lamination and edge sealing prevent the FE from the surface and edges. In addition, the types of surface laminating material also had a great impact to the emission.

Table 2 also presents the FE values and differences in the FE between the control and surface laminated samples with different types of surface laminating materials, and between un-sealed and sealed samples. When the surface of the control PB with un-sealed edges were laminated with LPL and PP, the emission decreased by 4.4% and 33.7%, respectively. And when all the edges of the control PB were sealed, the emission decreased by 14.1%, which further decreased by 37.4% and 80.7% upon the

Table 2. FE of PB, depending on types of the surface laminating material and state of edge sealing state

FE (mg/ℓ)	Control		LPL		PP	
	Un-sealed	Sealed	Un-sealed	Sealed	Un-sealed	Sealed
Average[1)]	5.03	4.32	4.81	3.15	3.33	0.97
Difference (%)[2)]	-	-	-4.4	-37.4	-33.7	-80.7
Difference (%)[3)]	-	-14.1	-	-34.5	-	-70.8

1) An average value of three replications
2) The FE difference between the control and surface laminated sample
3) The FE difference between the un-sealed and sealed samples

surface lamination with LPL or PP. The emission between the un-sealed and sealed PB with LPL or PP lamination decreased by 34.5% and 70.8%, respectively. These results indicate that types of surface laminating materials have a great impact on the FE from the surface of PB, and the emission from the edges also highly influence the FE of PB.

Fig. 3 displays the FE measurement results of MDF panels, depending on types of the surface laminating materials and state of the edge sealing. Compared to the FE level of PB, the FE of the control MDF was much lower. As expected, the FE of the control MDF samples decreased when the edges were sealed. The FE level of MDF slightly decreased when the same sample was laminated with PVC on the surfaces. In addition, the FE drastically decreased when their edges were sealed. However, the FE of MDF slightly increased when the surface was coated. This result could be resulted from the new edges of the specimen, which emitted formaldehyde from a solvent used for the coating. This explanation is further confirmed by the FE level of MDF sample with all edges sealed. In other words, the FE level of MDF with coating on the surface and all edges sealed decreased to a similar level of the sample with PVC lamination on the surface.

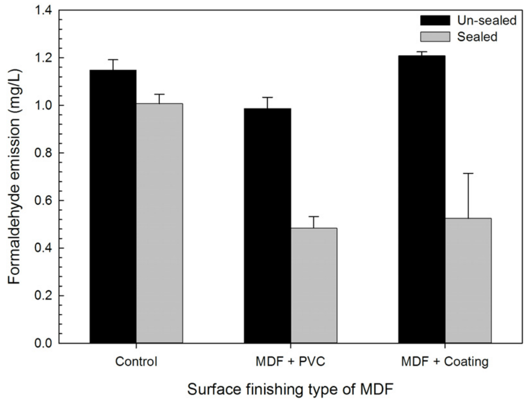

Fig. 3. FEs of MDF with different surface lamination materials and edge sealing states.

Table 3 also shows FE level of MDF, depending on the surface laminating materials and state of edge sealing. When all edges of the control sample were sealed, the FE decreased 12.3%. However, the FE of the control MDF decreased by 14% when the surfaces were laminated with PVC, which further reduced by 57.8% in the case of edge sealing. The FE of LPL laminated specimen decreased by 50.9% with the sealed edges. As mentioned, the FE of MDF sample with coating increased by 5.3%, but it considerably decreased by 54.3% com-

Table 3. FE of MDF, depending on laminating material types and edge sealing

FE (mg/ℓ)	Control		PVC		Coating	
	Un-sealed	Sealed	Un-sealed	Sealed	Un-sealed	Sealed
Average[1)]	1.148	1.007	0.987	0.484	1.209	0.525
Difference (%)[2)]	-	-	-14.0	-57.8	+5.3	-54.3
Difference (%)[3)]	-	-12.3	-	-50.9	-	-56.6

1) An average value of three replications
2) The FE difference between the control and surface laminated MDF
3) The FE difference between the un-sealed and sealed samples

pared to that of the control sample. The edge sealing of MDF with coating further reduced the FE by 56.6% when compared to that of the un-sealed sample. These results suggest that the surface lamination and edge sealing drastically reduce the FE of MDF, and the surface laminating material also have a great impact on the subsequent FE level.

4. CONCLUSION

This work was conducted to understand the effect of types of surface laminating materials and edge sealing to the FE level of PB and MDF panels, using 24-hour desiccator method. Four different types of surface laminating materials such as LPL, PP, PVC, or coating were used for either PB or MDF samples. The following conclusions were obtained from this study;

1. As expected, the FE of PB with the sealed edges decreased by 37.4% and 80.7% with the LPL and PP lamination, respectively. The surface laminated MDF with the sealed edges also showed a decrease in the emission up to 57.8% and 54.3%, with the PVC lamination and coating, respectively.
2. The coated MDF samples showed 5.3% increase in the FE when their edges were not sealed, indicating a FE form the solvent used for coating.
3. These results showed that the type of surface lamination material on wood-based composite panels has a great impact on their resultant FE, indicating that the influence of surface laminating materials should be taken into consideration for the formaldehyde emission measurement.

ACKNOWLEDGEMENT

The authors are grateful for the financial support from Kyungpook National University.

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