Characteristics on indoor air pollutant emission from wood-based flooring by environmental-friendly natural adhesive using CNSL

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Abstract

To discuss the reduction of formaldehyde and volatile organic compound (VOC) emissions from engineered flooring, cashew nut shell liquid (CNSL)-formaldehyde (CF) resin and CF/PVAc resin were applied for the maple face of the veneer bonding on plywood. The CF resin was used to replace urea-formaldehyde (UF) resin in the formaldehyde-based resin system in order to reduce formaldehyde and VOC emissions from the adhesives used between the plywoods and fancy veneers. For the CF/PVAc resins, 5, 10, 20 or 30% of PVAc was added to the CF resin. The CF/PVAc resins showed better bonding than the commercial natural tannin adhesive with a higher level of wood penetration. The standard formaldehyde emission test and a VOC analyzer were used to determine the formaldehyde and VOC emissions, respectively, from the engineered floorings. The CF resin and CF/PVAc resin systems with UV coating satisfied the E1 and E0 grades of the Korean Standard. TVOC emission was slightly increased by the PVAc addition.

Keywords: Environment-friendly resin, Cashew nut shell liquid (CNSL), Formaldehyde, TVOC, Wood-based flooring

Introduction

CNSL, an agricultural by-product of the cashew nut processing industry and a renewable resource, is a source of a long chain, m-substituted phenol which promises to be an excellent monomer for polymer production [1]. CNSL contains four major components: 3-pentadecenyl phenol (cardanol), 5-pentadecenyl resorcinol (cardol), 6-pentadecenyl salicylic acid (anacardic acid) and 2-methyl, 5 pentadecenyl resorcinol (2-methyl cardol) [2]. About 90% consists of anacardic acid, cardanol and cardol is CNSL [3]. Cardanol, which can be obtained by thermal treatment of CNSL, is a phenol derivative mainly composed of the meta substitute of a C15 unsaturated hydrocarbon chain with one to three double bonds [4,5]. Double vacuum distillation of CNSL yields pure cardanol at 50% yield[6]. The greatest problem of formaldehyde and TVOC emissions in engineered flooring is caused by the face of the fancy veneer bonding. UF resin is still used in industry in large quantity. The author’s previous work [7] suggested the suitability of Tannin as a renewable resource for surface bonding in engineered flooring. In this study, to reduce formaldehyde and VOC emissions from the resin for bonding the face of the fancy veneer on engineered flooring, the UF resin was replaced by natural CNSL.

Experimental

The plywood and decorative veneer used for fabricating the test samples were supplied by Easywood Co., Ltd., South Korea. The decorative veneers were 0.5 mm thick maple, while 7mm-thick plywoods manufactured in China were used. Polycardanol, which was prepared by enzyme-catalyzed oxidative polymerization, was kindly supplied by Hyundae Paint Co. Ltd, Korea. Figure 1 depicts the chemical structure of the polycardanol used in this work.

A formaldehyde solution of 40% weight of solid per unit volume of liquid and hexamine as a hardener were added to make the CF resin. The CF resin was polymerized by adding 1 ml of sodium hydroxide solution to the resin mixture. In the second stage of the experiment, 1 ml of 15% hexamine was also added [3]. Blends of various CF/polyvinyl acetate (PVAc) compositions were prepared. To make the CF/PVAc hybrid resin, 5, 10, 20 or 30 wt % of PVAc was added to CF and the mixture was stirred for 20 min. The engineered floorings for the formaldehyde and VOC emission tests were manufactured using natural tannin adhesive and CF/PVAc hybrid resin. After the resin was spread on the plywood, 0.5mm-thick maple fancy veneer was bonded by cold- and hot-pressing.

The formaldehyde emissions from the engineered floorings bonded with each blend were determined with a desiccator in accordance with the JIS method using a glass desiccator [9]. To determine VOC emissions we used a VOC analyzer. The VOC analyzer is a portable device to measure the four main aromatic hydrocarbon gases: toluene, ethylbenzene, xylene and styrene [10, 11].

Results and Discussion

Before surface coating, the formaldehyde emissions from the products glued with CF resin was already less than E1 grade (under 1.5 mg/L) of the formaldehyde emission level in the Korean Standard, even though the CF resin contained formaldehyde, as shown in Figure 2. The CF/PVAc hybrid adhesives samples showed a similar tendency to that of the CF resin. When the surface was coated with a UV-curable, urethane acrylate coating for flooring, the emission level was reduced to much less than half and satisfy the requirement of E0 grade. In the CF/PVAc resin system, the role of PVAc was to avoid generating formaldehyde emission, by replacement of CNSL with hexamine, and to increase the initial bonding strength through PVAc's high viscosity and room temperature curable property. Figure 3 presents the concentrations of the four indicated VOCs from the engineered flooring bonded with each resin system, as determined by the VOC analyzer. Xylene was the highest detected compound in all samples, followed by ethylbenzene and toluene. Styrene, however, was not detected at all in any of the systems. However, TVOC emission of the PVAc-added CF resin system was slightly increased compare to that of the CF resin.

Conclusions

The surface bonding strength of the CF/PVAc resins was higher than that of the CF resin. The bonding strength was maximized for the CF/PVAc resin with a PVAc content of 20%. By desiccator method, the formaldehyde emission, which presented similar emission data for the CF and CF/PVAc resins, was lowered with the PVAc addition, and further reduced when coated with a UV-curable urethane acrylate. The formaldehyde emission level was sufficiently reduced to satisfy the E0 grade of the Korean Standard. In the case of the CF/PVAc resin, the VOC emission measured by the VOC analyzer was slightly increased by the PVAc addition. In conclusion, the CF/PVAc resins were successfully applied as environmentally friendly adhesives of surface bonding for manufacturing engineered flooring.

Acknowledgments

This work was supported by the Grant of the Korean Ministry of Education, Science and Technology (The Regional Core Research Program/Biohousing Research Institute). This work was supported by the Biohousing Research Center.

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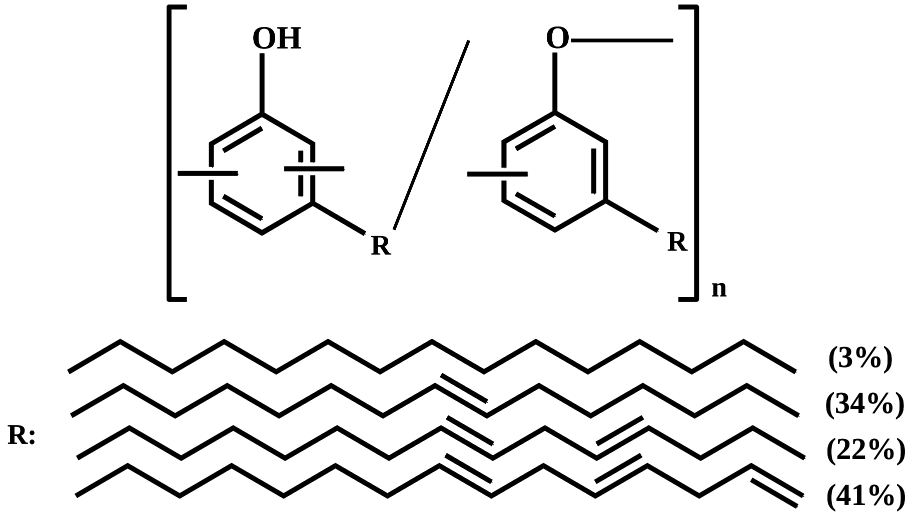

Fig. 1 Chemical structure of polycardanal

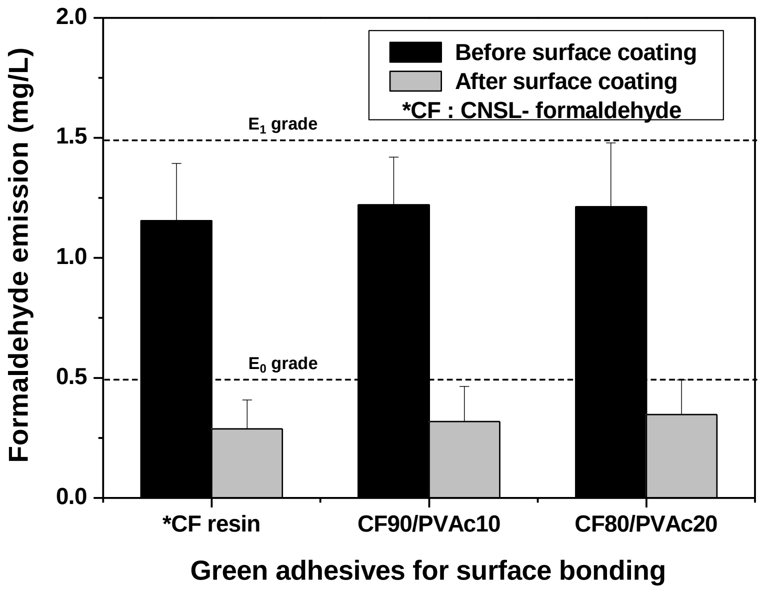

Fig. 2 Formaldehyde emission from engineered flooring bonded with CNSL-formaldehyde (CF) resin and CF/PVAc green adhesives as determined by the desiccator methodl

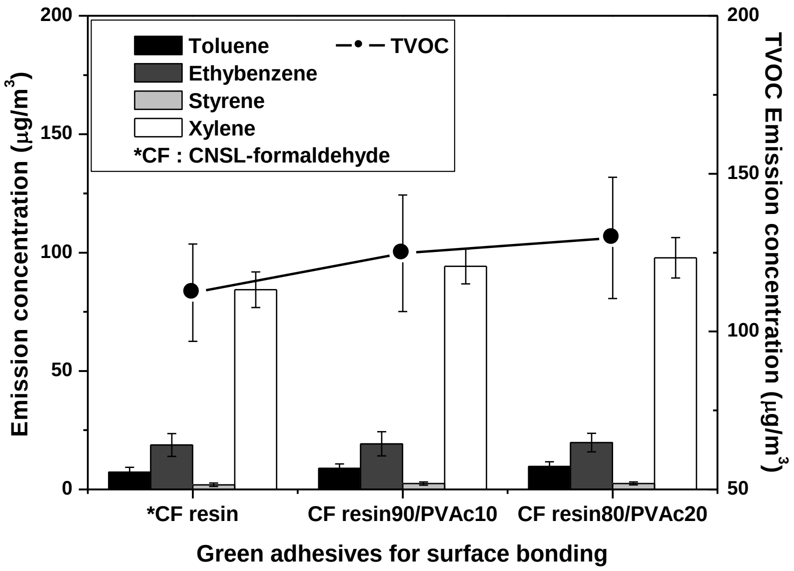

Fig. 3 VOC emission concentrations (toluene, ethylbenzene, xylene and styrene) from engineered flooring bonded with CNSL-formaldehyde (CF) resin and CF/PVAc green adhesives as determined by the VOC analyzer