

THE SORPTION OF WATER VAPOUR OF WOOD MODIFIED WITH ISOPROPYL GLYCIDYL ETHER

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ABSTRACT

The sorption isotherms for untreated and chemically modified wood with isopropyl glycidel ether were analysed using the Hailwood-Horrobin model. The experimental analysis of the sorption isotherms showed that etherification affects the total, polymolecular and monomolecular sorption. However, this reduction in hygroscopicity was lower than that of esterification with acetic anhydride, at comparable levels of modification.

KEY WORDS: wood, chemical modification, isopropyl glycidel ether, sorption isotherms, Hailwood-Horrobin model

INTRODUCTION

It has been demonstrated that wood may be modified chemically so that selected properties are enhanced in a more or less permanent fashion (Rowell 1983). Typical modifications of wood are esterifications and etherifications at the hydroxyl groups of the cell wall. Wood may be esterified with such chemicals as anhydrides, ketene, acid chlorides, carboxylic acids, isocyanates. Wood esterified with different types of anhydrides exhibited comparable dimensional stabilities and biological resistance (Matsuda 1987, Chang and Chang 2001, Chang and Chang 2002; Papadopoulos and Hill 2003, Papadopoulos 2005). Among the various esterification treatments, acetylation was the most emphatic and extensive one in applications (Feist et al. 1991, Ohkoshi 1996, Papadopoulos and Hill 2003, Papadopoulos 2005).

Wood also may be etherified with alkyl halogenides, epoxides, lactones, α , β -unsaturated compounds, of which epoxides are the most often used. During etherification with epoxides, wood was reacted with propylene oxide or butylene oxide catalyzed with triethylamine, forming ether bonds with new hydroxyl groups of the cell wall components. Etherified wood was found to be resistant to attack by subterranean termites and rot fungi, and to be more dimensional stable (Rowell et al. 1976, Rowell et al. 1979). Recently more wood-esterifying chemicals have been explored and the influences on wood properties after etherification examined (Paulsson and Paraks 2000, Evans et al. 2002). It has been recently shown that the dimensional stability of wood can be effectively improved by etherification with epoxides (Chang and Chang 2006). There is limited

work reported on the water vapour sorptive properties of such modified woods. The aim of this paper therefore, was to study the sorption of water vapour of wood modified with isopryl glycidyl ether. Adsorption isotherm was obtained to assess the hygroscopicity of esterified wood using the Hailwood-Horrobin sorption theory (Hailwood and Horrobin 1946).

MATERIAL AND METHODS

Wood modification reactions

Sapwood samples of dimension 20 mm x 20 mm x 5 mm (radial x tangential x longitudinal) were cut from freshly-felled kiln dried Corsican pine (*Pinus nigra*). Samples were carefully smoothed with sandpaper to remove loosely adhering fibres, then placed in a Soxhlet extractor for solvent extraction using toluene/methanol/acetone (4:1:1 by volume) for 8 h. and subsequently dried in an oven for 8 h at 105 °C. Samples were removed from the oven, transferred to a vacuum desiccator and allowed to cool to ambient temperature over silica gel. Prior to reaction, each sample was weighed on a four-figure balance. Samples (thirty replicates) were then vacuum immersed in neat isopropyl glycidyl ether with 5 % triethylamine for 1 h. The specimens in solution were then transferred to a flask set in an oil bath and heated at 120 °C for various periods of time to achieve different weight percent gains (WPG). At the end of the reaction period, the flask was removed from the oil bath, the hot reagent decanted off and ice cold acetone added to quench the reaction. Samples were kept in the acetone for 1 h, before being transferred to the Soxhlet apparatus for solvent extraction, as previously detailed. Samples were then oven dried at 105 °C for 8 h and weight gain due to reaction recorded.

Determination of moisture adsorption isotherms

Test samples were kept above saturated solutions of various salts in containers stored in a controlled temperature room set at 20 °C (variation +/- 1 °C). Six salts were chosen and these are listed in Tab. 1, along with the RH of the atmosphere above each saturated solution at 20 °C (according to Kaye and Laby 1973). They were chosen on the basis of giving minimum RH variation with changes in the temperature (Stamm 1964). Data published by Kaye and Laby (1973) show the equilibrium RH above saturated solutions of these salts to be insensitive to any variation in temperature expected in the controlled temperature room (a variation around 20 °C of +/-5 °C causing a maximum variation of +/- 1 % RH). Excess salt was always present within each solution to ensure saturation was maintained. The solution and air in the container were agitated by bubbling air through the solution. The oven dry wood samples were placed in the containers above saturated salt solutions. They were left to equilibrate for 4 weeks and then weighed once a week, using a four-place analytical balance until it became obvious that no significant weight change had occurred since the last weight was recorded (and equilibrium moisture content (EMC) had been attained). After, the adsorption equilibrium was attained samples were weighed, and moisture content was calculated on the oven dried weight basis.

RESULTS AND DISCUSSION

The values of A , B , C , coefficient of determination (R^2), K_1 , K_2 and W of various modified woods are presented in Tab. 1. The degree of fit, as measured by the coefficient of determination (R^2) is remarkably high indicating good fit to the experimental results. The physical constants K_1 ,

K_2 , W obtained were found to be in good agreement with those previously reported by Spalt (1958); Wangaard and Granados (1967) for unmodified wood and by Spalt (1958) and Papadopoulos (2005) for acetylated wood. For the modified wood, the W values increase as the WPG increases, indicating that a proportion of sites are made unavailable for water sorption.

Tab. 1: Fitted and physical constants calculated for the Hailwood–Horrobin adsorption isotherms

Wood	WPG	A	B	C	K_1	K_2	W_0	R^2
Control	0	3,25	11,52	10,88	5,78	0,77	294,8	0.99
Modified	7.5	4,22	14,11	12,75	5,51	0,73	366,3	0.89
Modified	15.2	5,37	17,59	16,91	5,21	0,77	466,8	0.83

The constant K_2 expresses the activity of dissolved water per unit relative vapour pressure. According to Okoh and Skaar (1980), its value should be unity if it has the same activity as liquid water. The K_2 values vary approximately between 0.72 and 0.76, indicating that the dissolved water shows a lower activity than the liquid water.

Adsorption isotherms are shown in Fig. 1. Equilibrium moisture content of modified wood was reduced at all relative humidities compared to the control, indicating a reduction in the hygroscopicity of wood. The adsorbed water was then separated into hydrate water relating to monomolecular sorption and into dissolved water relating to polymolecular sorption. The isotherms for monomolecular and polymolecular adsorption are plotted in Fig. 2, indicating a reduction in the hygroscopicity of wood at both monomolecular and polymolecular level.

Tab. 2: Reduction in the hygroscopicity (%) at saturation wood as a result of etherification with isopropyl glycidyl ether

Wood	WPG	Reduction in Hygroscopicity (%)		
		Total	Polymolecular	Monomolecular
Modified	7.5	24,5	26	20,5
Modified	15.2	33,7	32,2	37,7
Acetic ¹	15.3	41.7	41.3	42.5

1. Data from Papadopoulos (2005)

Tab. 2, presents the reduction in the hygroscopicity at saturation. It can be seen that the etherification with isopropyl glycidyl ether to 15.2% level of modification, was to reduce total sorption by 33.7%, polymolecular sorption by 32.2% and monomolecular sorption by 37.7% at saturation. In the bottom of the Table 2, data from wood modified with acetic anhydride at equivalent level of modification (15.9), is incorporated. In this case, the esterification with acetic anhydride reduced total sorption by 41.7%, polymolecular sorption by 41.3% and monomolecular

sorption by 42.5% at saturation. The better performance of wood modified with acetic anhydride may be attributed to strong ester bonds between acetic anhydride and wood.

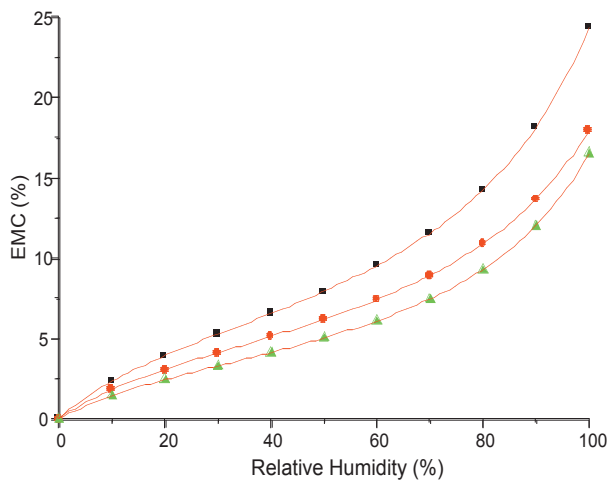


Fig. 1: Adsorption isotherms for unmodified (■), modified (7.5%) (●) and modified (15.2) (▲) wood with isopropyl glycidyl ether

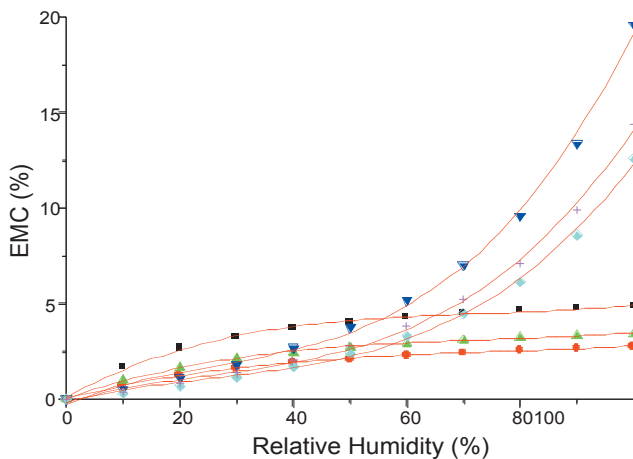


Fig. 2: Polymolecular adsorption isotherms for unmodified (▼), modified (7.5%) (+) and modified (15.2) (◆) wood with isopropyl glycidyl ether and monomolecular adsorption isotherms for unmodified (■), modified (7.5%) (▲) and modified (15.2) (●) wood with isopropyl glycidyl ether

CONCLUSIONS

The sorption isotherms for untreated and chemically modified wood with isopropyl glycidyl ether were analysed using the Hailwood-Horrobin model. The experimental analysis of the sorption isotherms showed that etherification affects the total, polymolecular and monomolecular sorption. However, this reduction in hygroscopicity was lower than that of esterification with acetic anhydride, at comparable levels of modification.

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