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Modification of alder wood with furfuryl alcohol

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Abstract: *Modification of alder wood with furfuryl alcohol*. The aim of this study was modification alder wood (*Alnus glutinosa* L.) with furfuryl alcohol and succinic anhydride as catalyst. The modification of wood was conducted out in two steps. In first step was treatment with a mixture of modifying wood, and then curing at 105 and 120°C. Use in the modification process furfuryl alcohol with succinic anhydride caused increase the values of WPG and complete discoloration of samples as evidenced the value of W_D.

Keywords: wood modification, furfuryl alcohol, succinic anhydride

INTRODACTION

The development of furfurylation began with with the research by Alfred J. Stamm in the 1950s (Stamm 1977). In the 1990 s, new catalytic system for wood furfurylation were developed (Schneider 1995, Westin 1995). By using cyclic carboxylics anhydrides as key catalysts, furfurylated wood with properties better than those produced by the previous system was obtained (Schneider 1995).

It has been known, that if wood is impregnated with FA and catalyst followed by heating a dark brown material if formed with advantageous properties compared to the untreated wood. Increased durability towards acid and alkali was one of the first fields of interest (Goldstein 1955), but also improved mechanical properties (Goldstein and Dreher 1960), dimensional stability (Lande at al. 2004a) and improved resistance towards biological degradation have been documented in a number of studies (Lande at al. 2004b). The products of furfurylation also have a dark colour (golden-brown and brown) and aesthetic appearance (Doczekalska et al. 2012).

The process of wood furfurylation is complex. It is influenced by the following parameters: process parameters (temperature, pressure), types of catalysts, stabilizers, pH of the environment of the reaction, presence of water.

The aim of this study was alder wood furfurylation with used succinic anhydride as a catalyst. They were determined: the degree of modification products (determined the weight percentage gain (WPG) indicators), the depth of penetration of the modifier (W_D) and dimensional stability (bulking coefficient BC).

MATERIALS AND METHODS

Wood: Alder wood – dimensions 20 x 20 x 310 mm – air conditioned at a temperature of 18°C ± 1°C and humidity 50% ± 2%.

Wood modification with furfuryl alcohol

The process of modification of wood with furfuryl alcohol consisted of two main stages: impregnation and curing. The modification mixture were consist of the following components: aqueous solution of furfuryl alcohol (FA) with concentration of 5 and 10% w/w of furfuryl alcohol or aqueous solution of furfuryl alcohol (FA) at concentrations of 5 and 10% with the addition of succinic anhydride in an amount of 1 and 4%.

Impregnation: Impregnation of wood was carried out under reduced pressure (7 bar). The vacuum was maintained for 45 min. and then raised to atmospheric pressure and were maintained for a further 2 hours.

Curing: In the second step, the samples were cured for 3 hours at 70°C. Then wrapped them in aluminium foil. Curing of samples was performed at 105°C or 120°C for 12 hours.

Weight percent gain index (WPG): The extent of reaction was calculated as weight percent gain (WPG) determined by the differences in oven dry weight of samples before modification (W_1) and after modification (W_2) according to equation (1):

$$WPG = \frac{W_2 - W_1}{W_1} \cdot 100[\%] \quad (1)$$

Penetration depth is performed using the Brinell magnifying glass. The modified sample was cut in three places: in the middle of the length and 15 mm from each front. Using the Brinell magnifying glass measured with an accuracy of 0,1 mm penetration depth in location distant from each other about 5 mm. Index of diffusion (W_D) was calculated for each section and the average for whole sample according to equation (2):

$$W_D = \frac{P_P}{P_C} \quad (2)$$

where:

P_P – discoloured cross-section area; P_C – the total cross-section area

Dimensional stability of the sample was determined using the bulking coefficient (BC), defined as follows:

$$BC = \frac{V_M - V_U}{V_U} \cdot 100[\%] \quad (3)$$

where:

V_U – volume of the unmodified wood sample; V_M - volume of the modified wood sample.

RESULTS AND DISCUSSION

Table 1 presents the results of the determined percentage of the sample weight changes of the alder wood. WPG values differ depending on the composition of the impregnation mixture and the curing temperature.

The values of WPG for alder wood modified 5% of FA solution and curing at 105°C amounts to 27.69%. Addition of succinic anhydride to furfuryl alcohol, in an amount of 1%, caused a decrease WPG to about 23%. However, the WPG index for modified wood with 5% FA with 4% addition of succinic anhydride amounts to 30.59%.

Alder wood impregnated with 5% and 10% FA solutions and curing at 120°C is characterized by lower values of WPG. The lowest values of this index obtained for the modification carried out only with furfuryl alcohol (table 1).

WPG index of alder wood modified 10% FA solution and curing at 105°C amounts to 13.36%. It was observed that higher amount of catalyst in the impregnation mixture caused an increase value of WPG of modified wood. A similar trend show alder wood samples impregnated and cured at 120°C.

Tab. 1 Weight percent gain index (WPG) [%]

	Temperature	
	105°C	**120°C**
5% FA	27,69 %	0,88 %
5% FA + 1% SA	23,17 %	7,18 %
5% FA + 4% SA	30,59 %	16,11 %
10% FA	13,36 %	0,00 %
10% FA + 1% SA	24,23 %	9,73 %
10% FA + 4% SA	29,48 %	17,60 %

Table 2 shows the bulking coefficient (BC) of modified alder wood. The bulking coefficient is related to dimensional stability of the samples, which is closely related to the value of WPG (Baysal et al. 2004). It was observed that increased index of WPG accompanied by increased values of BC index (tables 1 and 2).

Tab. 2 Bulking coefficient (BC) [%]

	Temperature	
	105°C	**120°C**
5% FA	11,54 %	0,10 %
5% FA + 1% SA	7,62 %	0,50 %
5% FA + 4% SA	13,94 %	1,62 %
10% FA	4,65 %	0,13 %
10% FA + 1% SA	9,41 %	0,23 %
10% FA + 4% SA	9,46 %	4,82 %

The lowest values of index of diffusion (W_D) were determined for samples undergone modification with furfuryl alcohol solutions without the addition of succinic anhydride (table 3). W_D index values obtained for these samples, indicate only surface discoloration of alder wood caused modification process. Addition of succinic anhydride to furfuryl alcohol caused an increase W_D index to 1. This W_D index value indicates that samples were discolored across their volume independently of compositions of impregnation mixture and curing temperature.

Tab. 3 Index of diffusion (W_D)

	Temperature	
	105°C	**120°C**
5% FA	0,02	0,10
5% FA + 1% SA	1,00	1,00
5% FA + 4% SA	1,00	1,00
10% FA	0,03	0,02
10% FA + 1% SA	1,00	1,00
10% FA + 4% SA	1,00	1,00

CONCLUSIONS

On the basis of research on modification of alder wood with furfuryl alcohol and succinic anhydrides as a catalyst was found:

a) the value of the index WPG modified alder wood is influenced: percentage concentration of furfuryl alcohol solution, the amount of added catalyst, curing temperature treated wood,
b) use in the modification process furfuryl alcohol with succinic anhydride caused increase the values of WPG,
c) use in the modification process furfuryl alcohol with succinic anhydride caused complete discoloration of samples as evidenced the value of W_D.

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Streszczenie: *Modyfikacja drewna olchy alkoholem furfurylowym*. W pracy modyfikowano drewno olchy alkoholem furfurylowym z dodatkiem bezwodnika bursztynowego jako katalizatora. Modyfikacja drewna była prowadzona w dwóch etapach. W pierwszym etapie drewno nasycano mieszaniną modyfikującą, w drugim wygrzewano w temperaturze 105°C i 120°C. Ocenę stopnia modyfikacji drewna alkoholem furfurylowym dokonano na podstawie: wskaźnika procentowej zmiany masy (WPG), wskaźnika dyfuzji (W_D), współczynnika zmiany objętości (BC). Na wartość WPG modyfikowanego drewna olchy wpływ mają: stężenie procentowe roztworu alkoholu furfurylowego, ilość dodanego katalizatora, temperatura wygrzewania zaimpregnowanego drewna. Wzrost procentowego udziału bezwodnika bursztynowego w mieszaninie modyfikującej powoduje wzrost wartości wskaźnika WPG. Obecność katalizatora w roztworze impregnującym powoduje całkowite przebarwienie próbek drewna na co wskazują wartości wskaźnika dyfuzji (W_D).

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