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PROPERTIES OF PARTICLEBOARDS RESINATED WITH ESTER-MODIFIED PF RESIN PART C. THE EFFECT OF THE TYPE OF ESTER-FORMING ALCOHOL ON THE POSSIBILITY TO LOWER PRESSING TEMPERATURE

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Abstract. The study investigated the effect of the modification of phenolic resin with organic acid esters, such as ethyl, butyl and pentyl acetates, on the possibility to lower pressing temperature of particleboards manufactured using ester-modified PF resin. Conducted tests showed that the applied modification of phenolic resin makes it possible, within the adopted range of pressing temperatures, to produce particleboards with considerably better mechanical properties. It also needs to be stressed that at lower pressing temperatures the effect of the applied modification is so intense that boards pressed at 160°C obtain strength values comparable or even higher than those of the control board pressed at 180°C.

Key words: PF resin, particleboard, ester, pressing temperature

INTRODUCTION

An essential problem in the production of wood based materials, which are to be used under changing environmental conditions, is the question whether to use much more expensive, but highly reactive PMDI resins or to apply a cheaper and technologically well-tried phenol-formaldehyde (PF) resin. The latter, however, is considered to be low-active and thus requiring either longer times or higher temperatures of the board pressing process. Studies conducted so far by these authors on the improvement of reactivity of phenolic resin using organic acid esters [Łęcka et al. 2001, Mirski et al. 2004] confirmed the findings of Fidelus [1983] and Pizzi and Stephanou [1994] on not only the increase in the reactivity of PF resin itself, but also on the considerably improved properties of particleboards produced with the use of modified resin. Moreover, it was shown that the type of acid forming the ester has a considerable effect on the possibility to both shorten

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the time [Mirski et al. 2002] and to lower the temperature of pressing in case of boards resinated with PF resin modified with esters [Mirski et al. 2003]. Thus, for example the application of ethyl butyrate makes it possible to shorten pressing time by 30%, or to lower the temperature of this process by 20°C, with no deterioration of physical and mechanical properties of produced boards, while the application of ethyl acetate makes it possible to produce boards at the unchanged time with comparable or slightly improved properties. On the other hand, investigations on the effect of the type of ester-forming alcohol showed that properties of the produced boards are improving along with an increase in the length of the alkyl chain of the ester-forming alcohol group. Using butyl acetate as a modifier of PF resin it is possible to produce, under conditions considered standard ones, particleboards with considerably improved properties [Mirski et al. 2004], while at pressing time shortened by 1.5 min – boards with properties comparable to those of control boards pressed for the identical time [Mirski et al. 2005]. For this reason it was attempted in this study to determine the effect of the type of ester-forming alcohol on the possibility to lower pressing temperature of particleboards manufactured using ester-modified PF resin.

MATERIAL AND METHODS

Phenol-formaldehyde resin used in this study is commonly applied in the production of particleboards, which are to be used under humid conditions, and it has the following characteristics:
- dry matter: 45.2%,
- density: 1.112 g/cm^3,
- free phenol content: 0.02%,
- free formaldehyde content: 0.026%,
- viscosity according to Ford no. 4/20ºC: 106 s,
- gelling time at 130ºC: 146 s,
- pH: 12.52.

Acetic acid esters and esters of ethyl, butyl and amyl alcohol were used as modifiers of phenolic resin in the amount of 0.05 mole per 100 g d. m. resin.

Particleboards with the dimensions of 600 × 500 × 12 mm, density of 700 kg/m^3 and resination of 8% were manufactured under laboratory conditions in a semi-automatic press by Simpelkampf, applying the following pressing conditions:
- temperature: 160°C, 170°C, 180°C, 190°C, 200°C,
- time: 5 min,
- pressure: 2.5 MPa.

Particleboards manufactured in this way were tested according to respective standards in terms of such properties as:
- swelling in thickness after 24 h according to PN-EN 317,
- internal bond IB according to PN-EN 319,
- water resistance in terms of the V-100 test according to PN-EN 1087-1,
- modulus of rupture MOR according to PN-EN 310,
- modulus of elasticity MOE according to PN-EN 310.

RESULTS AND DISCUSSION

Water resistance of particleboards resinated with modified PF resin

Results of water resistance tests of particleboards resinated with ester-modified PF resin, measured by their swelling in thickness and internal bond after the boiling test, are presented in Tables 1 and 2.

It results from the investigations that values of swelling for boards resinated with estermodified PF resin fall within the range of values obtained for control boards practically in the whole range of investigated temperatures (Table 1). Slightly lower values of swelling in thickness were obtained only in case of resin modified with amyl acetate; however, the improvement in the hydrophobicity of boards defined by this parameter did not

Table 1. The effect of the pressing temperature on the swelling of particleboards glued with PF resin modified with esters
Tabela 1. Wpływ temperatury prasowania na spęcznienie płyt wiórowych zaklejanych żywicą PF modyfikowaną estrami

Pressing temperature Temperatura prasowania °C	Swelling, % Spęcznienie, %											
	PF			ethyl acetate octan etylu			butyl acetate octan butylu			amyl acetate octan pentylu		
	ā	σ	v	ā	σ	v	ā	σ	v	ā	σ	v
160	33.6	2.8	8.3	33.1	2.6	7.9	31.9	1.6	5.0	32.2	3.4	10.6
170	32.4	2.6	8.0	31.7	1.2	3.8	31.2	2.2	7.1	30.2	1.8	6.0
180	29.5	0.8	2.7	31.6	3.0	9.5	30.0	2.8	9.3	27.6	1.4	5.1
190	26.6	1.8	6.8	29.3	1.4	4.8	26.0	2.2	8.5	25.2	1.4	5.6
200	25.6	2.2	8.6	28.4	1.2	4.2	25.8	1.0	3.9	22.7	1.8	7.9

Table 2. The effect of the pressing temperature on the moisture resistance of particleboards glued with PF resin modified with esters
Tabela 2. Wpływ temperatury prasowania na wytrzymałość na rozciąganie prostopadłe do płaszczyzn płyty po próbie gotowania

Pressing temperature Temperatura prasowania °C	Moisture resistance, MPa Wytrzymałość po próbie gotowania, MPa											
	PF			ethyl acetate octan etylu			butyl acetate octan butylu			amyl acetate octan pentylu		
	ā	σ	v	ā	σ	v	ā	σ	v	ā	σ	v
160	0.22	0.02	9.1	0.41	0.06	14.6	0.41	0.05	12.2	0.48	0.04	8.3
170	0.35	0.03	8.6	0.40	0.08	20.0	0.43	0.07	16.3	0.47	0.03	6.4
180	0.40	0.03	7.5	0.39	0.04	10.3	0.45	0.03	6.7	0.48	0.03	6.3
190	0.41	0.02	4.9	0.42	0.04	9.5	0.46	0.05	10.9	0.52	0.05	9.6
200	0.46	0.03	6.5	0.43	0.05	11.6	0.50	0.06	12.0	0.54	0.03	5.6

exceed 10%. In turn, the results of strength testing of particleboards resinated with both non-modified and ester-modified PF resins and subjected to the boiling test showed that strength of boards resinated with such modified resin and pressed at the temperature of 160°C is almost twice as high as that of boards resinated with non-modified resin. On the other hand, increasing pressing temperature by 10°C or by 20°C has an intensive effect only on the increase in strength of boards resinated with non-modified resin. The observed increase in strength of these boards, at a low coefficient of variation, was in the first case almost 60%, while in the second case – over 80%, respectively. In contrast, in case of boards resinated with ester-modified resin, taking into consideration the values of standard deviations (0.03-0.08) it was found that a decrease in temperature from 180°C to 160°C did not cause a drop in internal bond after the boiling test. However, the highest strength was found for boards resinated with PF resin with the addition of amyl acetate. Thus, particleboards resinated with resin with the addition of this modifier exhibit strength as much as 120% higher than that of control boards when the temperature of heating press platens is 160°C, although only 20% higher strength when boards were manufactured at the temperature of 180°C.

Mechanical properties of particleboards resinated with modified PF resin

Results of testing mechanical properties of boards resinated with ester-modified PF resin are presented in Tables 3 to 5.

It results from the conducted tests that internal bond of boards manufactured at 160--170°C generally is not affected by the type of the applied modifier. Strength values obtained for boards resinated with ester-modified resin are by 15-20% higher than those of control boards in case of board production at the temperature of 160°C, and by approx. 25% when the temperature of heating press platens is 170°C. In contrast, a varied effect of the applied modifiers on internal bond is observed at higher temperatures. Thus, in case of the application of ethyl acetate or amyl acetate as modifiers of PF resin the maximum strength was obtained at pressing temperature of 180°C, while a further increase in temperature results in a decrease of the previously obtained value,

Table 3. The effect of the pressing temperature on the internal bond of particleboards glued with PF resin modified with esters
Tabela 3. Wpływ temperatury prasowania na wytrzymałość na rozciąganie prostopadłe do płaszczyzn płyty

Pressing temperature Temperatura prasowania °C	Internal bond, MPa Wytrzymałość na rozciąganie prostopadłe do płaszczyzn płyty, MPa											
	PF			ethyl acetate octan etylu			butyl acetate octan butylu			amyl acetate octan pentylu		
	ā	σ	v, %	ā	σ	v, %	ā	σ	v, %	ā	σ	v, %
160	0.42	0.02	4.8	0.49	0.04	8.2	0.50	0.03	6.0	0.48	0.03	6.3
170	0.45	0.04	8.9	0.56	0.04	7.1	0.55	0.03	9.1	0.55	0.03	5.5
180	0.52	0.02	3.8	0.68	0.05	7.3	0.60	0.05	8.3	0.67	0.04	6.0
190	0.55	0.04	7.3	0.57	0.03	5.3	0.67	0.04	6.0	0.59	0.03	5.1
200	0.58	0.05	8.6	0.63	0.03	4.8	0.68	0.04	5.9	0.60	0.04	6.7

Table 4. The effect of the pressing temperature on the modulus of rupture of particleboards glued with PF resin modified with esters
Tabela 4. Wpływ temperatury prasowania na wytrzymałość na zginanie statyczne

Pressing temperature Temperatura prasowania °C	Modulus of rupture, MPa Wytrzymałość na zginanie, MPa											
	PF			ethyl acetate octan etylu			butyl acetate octan butylu			amyl acetate octan pentylu		
	ā	σ	*v*, %	ā	σ	*v*, %	ā	σ	*v*, %	ā	σ	*v*, %
160	15.4	1.5	9.7	17.0	0.7	4.1	20.2	0.8	4.0	18.7	0.6	3.2
170	16.1	1.2	7.5	19.2	0.8	4.2	22.3	0.9	4.0	21.1	1.5	7.1
180	16.3	1.5	9.2	20.6	0.9	4.4	23.0	1.1	4.8	23.6	0.9	3.8
190	18.5	0.9	4.9	21.5	0.9	4.2	23.8	0.8	3.4	24.1	1.6	6.6
200	19.9	1.2	6.0	21.7	0.9	4.1	24.8	0.9	3.6	24.5	0.9	3.7

Table 5. The effect of the pressing temperature on the modulus of elasticity of particleboards glued with PF resin modified with esters
Tabela 5. Wpływ temperatury prasowania na moduł sprężystości

Pressing temperature Temperatura prasowania °C	Modulus of elasticity at bending, MPa Moduł sprężystości, MPa											
	PF			ethyl acetate octan etylu			butyl acetate octan butylu			amyl acetate octan pentylu		
	ā	σ	*v*, %	ā	σ	*v*, %	ā	σ	*v*, %	ā	σ	*v*, %
160	2150	120	5.6	2380	150	6.3	2640	130	4.9	2490	110	4.4
170	2230	160	7.2	2510	100	4.0	3000	190	6.3	2800	190	6.8
180	2320	160	6.9	2740	150	5.5	3220	230	7.1	3220	120	3.7
190	2470	180	7.3	2840	140	4.9	3380	150	4.4	3250	180	5.5
200	2550	130	5.1	2810	150	5.3	3420	220	6.4	3270	230	7.0

although mean strength values are still higher than those obtained for control boards. In turn, the application of butyl acetate as a modifier results in strength increasing along with pressing time and for the temperature of 200°C at comparable values of coefficients of variation the obtained value was by 0.1 MPa higher than that of the control board pressed under identical conditions.

The applied modifiers of PF resin made it possible also in the adopted range of pressing temperatures to manufacture boards with higher modulus of rupture (Table 4) than those produced with the use of non-modified resin. Already at pressing temperature of 160°C strength of boards resinated with resin with added esters is much higher than that of boards produced with non-modified resin. Thus, in case of applied amyl or butyl acetate it is higher by 21% and 30%, respectively. As could have been expected, along with an increase in pressing time a further increase in modulus of rupture was observed both in boards resinated with non-modified resin and those resinated with modified PF resin, and an increase in the temperature of heating press platens from 160°C to 200°C caused an adequate increase in strength of particleboards on average by 4.5 MPa.

A similar trend was observed in the case of modulus of elasticity (Table 5). As it was shown by the conducted tests, boards resinated with ester-modified resin show a considerably higher value of modulus of elasticity in the whole range of applied pressing temperatures, although the highest values of this modulus are found for boards manufactured using resin modified with butyl acetate. Modulus of elasticity for these boards pressed at 160°C and 200°C is higher by 23 and 30%, respectively, than modulus of elasticity of control boards manufactured under identical conditions.

CONCLUSIONS

The conducted tests showed that the applied modification of phenolic resin makes it possible, within the adopted range of pressing temperatures, to produce particleboards with considerably better mechanical properties. The applied esters result in a significant improvement of such properties as internal bond, modulus of rupture and modulus of elasticity. It also needs to be stressed that at lower pressing temperatures the effect of the applied modification is so intense that boards pressed at 160°C obtain strength values comparable or even higher than those of the control board pressed at 180°C. Butyl acetate turned out to be the most effective modifier.

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WŁAŚCIWOŚCI PŁYT WIÓROWYCH ZAKLEJANYCH ŻYWICĄ FENOLOWO-FORMALDEHYDOWĄ MODYFIKOWANĄ ESTRAMI CZĘŚĆ C. WPŁYW RODZAJU ALKOHOLU TWORZĄCEGO ESTER NA MOŻLIWOŚĆ OBNIŻENIA TEMPERATURY PRASOWANIA PŁYT

Streszczenie. W pracy zbadano wpływ modyfikacji żywicy fenolowej estrami kwasów organicznych takimi, jak octan etylu, butylu oraz pentylu, na możliwość obniżenia temperatury prasowania płyt wiórowych, wytwarzanych z użyciem zmodyfikowanej żywicy PF. Przeprowadzone badania wykazały, iż zastosowana modyfikacja żywicy fenolowej pozwala, w stosowanym zakresie temperatur prasowania, na wytworzenie płyt wiórowych o znacznie lepszych właściwościach mechanicznych. Należy podkreślić, iż w niższych temperaturach prasowania wpływ zastosowanej modyfikacji jest na tyle intensywny, że płyty prasowane w temp. 160°C uzyskują wartości porównywalne lub nawet wyższe niż płyty kontrolne prasowane w 180°C.

Słowa kluczowe: żywica PF, płyta wiórowa, estry

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