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PROPERTIES OF PARTICLEBOARDS RESINATED WITH PF RESIN MODIFIED WITH DIOL ESTERS

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Abstract. Tests showed that PF resin modification with diol esters makes it possible – when maintaining identical pressing parameters – to manufacture particleboards with improved mechanical properties and enhanced water resistance in comparison to the control board resinated with pure PF resin. The application of diol esters as modifiers of phenolic resin makes it also possible to produce – at reduced temperature or shortened pressing time – particleboards with good mechanical properties and high water resistance. However, no significant differences were observed in board properties depending on the type of diol forming the ester.

Key words: PF resin, esters, particleboard

INTRODUCTION

This study is a continuation of investigations on enhancing the reactivity of PF resin applied to manufacture wood-based materials with increased water resistance. Analyses conducted so far by the authors of this study showed that esters of organic acids applied as modifiers of phenolic resin make it possible – at identical pressing conditions – to produce particleboards with very good physical and mechanical properties [Łęcka et al. 2001 b, Mirski et al. 2004]. Moreover, they also make it possible to manufacture boards with properties meeting the requirements of respective standards at shortened pressing time and reduced pressing temperature [Mirski et al. 2005 a, 2006]. It is known that in the alkaline environment of PF resin esters undergo an irreversible reaction of hydrolysis to alcohols and acids forming them. In contrast, experiments conducted by the authors of this study showed that diols applied as modifiers of PF resin make it possible – under identical pressing conditions – to manufacture particleboards with improved physical and mechanical properties in comparison to boards resinated with non-modified resin, while at shortened pressing time – boards with properties comparable to those of the control board [Łęcka et al. 2001 a, Mirski et al. 2005 b]. In the opinion of the authors, high effectiveness of phenolic resin reactivation by alcohols results from their being embedded in the resin structure [Mirski et al. 2005 c].

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In turn, the aim of this study was to investigate the effect of diol esters on particleboard properties and the feasibility of reducing pressing temperature or pressing time for boards manufactured using such modified PF resin.

MATERIAL AND METHODS

PF resin used to produce particleboards with improved moisture resistance was used in the experiments. It had the following characteristics: dry resin solids – 45.7%, density – 1.112 g/cm^3, free phenol content – 0.02%, free formaldehyde content – 0.026%, viscosity according to Ford no. 4/20°C – 106 s, gelation time at 130°C – 46 s and pH – 12.52. Propylene glycol diacetate and ethylene glycol diacetate were used as modifiers PF resin. Selected esters were added to resin in the amounts of 0, 0.01, 0.025 and 0.05 mole per 100 g dry resin solids.

Properties of the modified PF resin were determined by means of measuring:
- pot life at a temperature of 20°C on the basis of measured dynamic viscosity of glue solutions,
- gel time at the temperature of 130°C.

Single-layer particleboards with the density of 700 kg/m^3 and the thickness of 12 mm were manufactured under laboratory conditions from pine chips and modified resin, applying the following pressing parameters:
- unit pressure 2.5 N/mm^2,
- pressing time 25, 22, 20 and 17 s/mm,
- temperatures 160, 180, 190 and 200°C,
- resination rate 8%.

Particleboards manufactured in this way were tested according to respective standards in terms of such properties as:
- modulus of rupture and modulus of elasticity according to PN-EN 310,
- internal bond according to PN-EN 319,
- internal bond after the boiling test according to PN-EN 1087-1,
- swelling in thickness according to PN-EN 317.

RESULTS AND DISCUSSION

Properties of liquid PF resin modified with esters

Results of analyses of the effect of PF resin modification with diol esters on its gelation time are presented on Figure 1. Generally it may be stated that esters applied as additives to PF resin considerably accelerate resin gelation, with gelation time being shortened in proportion to the amounts of esters added to resin. However, differences between gelation times recorded under the influence of the addition of individual modifiers in the amounts up to 0.05 mole were slight and did not exceed 10%. In turn, increasing the amount of modifiers considerably intensified resin curing, especially that modified with ethylene diacetate. Thus, while gelation time of a solution of resin modified

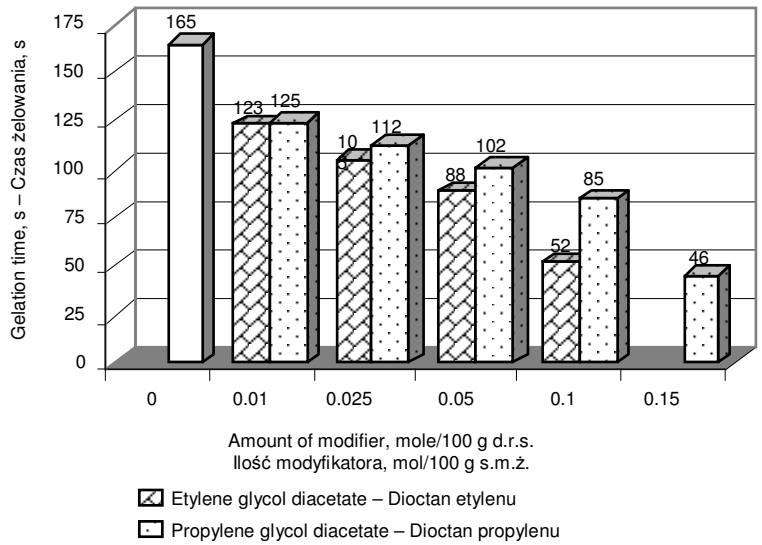

Fig. 1. Gelation time of ester-modified PF resin
Rys. 1. Czas żelowania żywicy PF modyfikowanej estrami alkoholi wielowodorotlenowych

with propylene diacetate introduced to resin in the amount of 0.15 mole/100 g d.r.s. was shortened by over 70%, ethylene diacetate introduced in the identical amount resulted in prompt resin gelation.

In turn, experiments concerning pot life of modified resin showed that diol esters added to PF resin even in very small amounts considerably accelerated an increase in their viscosity, especially in the initial time of measurements (Table 1). Thus, when ethylene and propylene diacetates were introduced in the amount of 0.025 mole after 4 h

Table 1. Pot life of ester-modified PF resin
Tabela 1. Żywotność żywicy PF modyfikowanej estrami alkoholi diwodorotlenowych

Type of modifier Rodzaj modyfikatora	Amount mole/100 g d.r.s. Ilość mol/100 g s.m.ż.	Measurement time, h – Pomiar po czasie, h				
		0	4	8	12	24
		Dynamic viscosity, mPa·s – Lepkość dynamiczna, mPa·s				
	0	520	520	530	530	535
Ethylene glycol diacetate Dioctan etylenu	0.01	495	940	1 065	1 100	1 140
	0.025	465	2 120	2 515	2 610	2 780
	0.05	445	–	–	–	–
Propylene glycol diacetate Dioctan propylenu	0.01	485	825	885	950	1 250
	0.025	465	995	1 605	2 220	2 325
	0.05	395	2 430	5 185	–	–

an increase in viscosity was recorded in relation to non-modified resin by over 300% and 100%, respectively. At successive time intervals a further increase in viscosity was observed; however, with time it was becoming less intensive. It suggests that such a considerable increase in viscosity on the one hand is caused by the catalytic action of acetic acid released from the ester as a result of its hydrolysis, on the other hand by the possible embedding of the forming difunctional alcohol into resin structure [Tohmura and Higuchi 1995, Mirski et al. 2005 c].

Results of these experiments showed that both esters applied in the amounts exceeding 0.05 mole resulted in a considerable increase in its reactivity, thus preventing the application of such modified resin in particleboard production (Fig. 1, Table 1). For this reason, in further studies particleboards resinated with modified resin were manufactured with an addition of modifiers in the amount of 0.05 mole/100 g d.r.s.

Properties of particleboards resinated with ester-modified PF resin

Results of tests concerning properties of particleboards depending on the amounts and types of applied modifiers are presented in Table 2. As it results from these data, diol esters to a considerable degree improve strength properties of manufactured boards. Thus, irrespective of the type of ester internal bond increased almost 2.5 times with an increase in the amount of added modifiers, whereas bending strength – irrespective of their amounts – remained similar, on average by 50% higher than that of the control board. Water resistance of boards also improved considerably, both measured by their swelling in thickness after soaking in water and that defined after the boiling test. Swelling in thickness recorded at the maximum amounts of both esters decreased on average by 6%, while strength after the boiling test increased by over 100%.

Table 2. Properties of particleboards depending upon the kind and amount of the ester added to PF resin

Tabela 2. Właściwości płyt wiórowych w zależności od rodzaju i ilości estru dodawanego do żywicy PF

Type of modifier Rodzaj modyfikatora	Amount mole/100 g d.r.s. Ilość mol/ 100 g s.m.ż.	Swelling Spęcznienie %		V-100 N·mm^{-2}		IB N·mm^{-2}		MOR N·mm^{-2}		MOE N·mm^{-2}	
Control board Płyta kontrolna	0	29.5	*5.3*	0.4	*0.08*	0.52	*0.13*	15.3	*2.1*	2 520	*360*
Ethylene glycol diacetate Dioctan etylenu	0.01	28.1	*4.1*	0.67	*0.09*	1.08	*0.18*	20.6	*2.4*	2 950	*350*
	0.025	23.9	*5.0*	0.78	*0.11*	1.15	*0.16*	23.3	*2.4*	3 310	*265*
	0.05	22.3	*5.2*	0.86	*0.15*	1.27	*0.13*	23.7	*2.8*	3 450	*310*
Propylene glycol diacetate Dioctan propylenu	0.01	27.5	*6.0*	0.65	*0.14*	1.02	*0.18*	22.5	*2.1*	3 170	*335*
	0.025	25.4	*3.5*	0.75	*0.13*	1.12	*0.2*	23.4	*2.2*	3 260	*360*
	0.05	24.1	*2.9*	0.88	*0.23*	1.25	*0.18*	23.4	*1.6*	3 280	*380*

Standard deviation – italics.
Odchylenie standardowe – italiki.

Table 3 presents testing results of the effect of pressing time on properties of particleboards resinated with PF resin modified with diol esters added in the amount of 0.05 mole/100 g d.r.s. As it results from the data given in the table, shortening of pressing time does not result in a significant deterioration of their properties. Experiments conducted in this respect showed that shortening of pressing time by 30% still makes it possible to manufacture boards exhibiting good properties. Thus, if modulus of elasticity is similar to that of the control board, bending strength in comparison to that of the control board increases by approx. 20%. Moreover, boards manufactured under these conditions meet the requirements of the respective standard in terms of internal bond (0.45 according to EN 312-5). In turn, water resistance measured by internal bond after the boiling test decreased with shortening of pressing time, although it still remained at a much higher level than that required by the standard (0.15 according to EN 312-5).

Table 3. The effect of pressing time on the properties of particleboards glued with ester-modified PF resin

Tabela 3. Wpływ czasu prasowania na właściwości płyt wiórowych zaklejanych żywicą PF modyfikowaną estrami

Type of modifier Rodzaj modyfikatora	Pressing time Czas prasowania min	Swelling Spęcznienie %		V-100 N·mm^{-2}		IB N·mm^{-2}		MOR N·mm^{-2}		MOE N·mm^{-2}	
Control board Płyta kontrolna	5.0	29.5	*5.3*	0.4	*0.08*	0.52	*0.13*	15.3	*2.1*	2 520	*360*
Ethylene glycol diacetate Dioctan etylenu	5.0	22.3	*5.2*	0.86	*0.15*	1.27	*0.13*	23.7	*2.8*	3 450	*310*
	4.5	22.9	*3.6*	0.64	*0.14*	1.11	*0.11*	23.1	*0.7*	3 250	*280*
	4.0	24.1	*2.9*	0.59	*0.13*	0.65	*0.13*	19.9	*0.5*	2 700	*265*
	3.5	26.4	*3.2*	0.39	*0.09*	0.45	*0.06*	18.3	*1.3*	2 530	*290*
Propylene glycol diacetate Dioctan propylenu	5.0	24.1	*3.9*	0.88	*0.23*	1.25	*0.18*	23.4	*1.6*	3 280	*380*
	4.5	26.3	*3.8*	0.69	*0.08*	1.02	*0.12*	23.0	*0.7*	3 130	*320*
	4.0	28.7	*4.6*	0.52	*0.11*	0.64	*0.11*	22.7	*0.8*	3 000	*300*
	3.5	29.3	*5.6*	0.35	*0.09*	0.48	*0.07*	18.6	*1.2*	2 550	*350*

Standard deviation – italics.
Odchylenie standardowe – italiki.

In turn, tests conducted to investigate the possible reduction of pressing temperature showed that the application of such modified resin makes it possible to manufacture – at pressing temperature reduced by 20°C – particleboards with mechanical properties generally at a level of those reported for boards resinated with pure PF resin and pressed at 180°C. Thus, as it results from data presented in Table 4 boards manufactured under these conditions exhibited bending strength, modulus of elasticity and swelling in thickness after soaking in water, improved in comparison to those of the control board on average by 19, 8 and 9%, respectively. In turn, although internal bond, measured both during the dry test and after the boiling test, deteriorated, it still met the requirements of

Table 4. The effect of the pressing temperature on the properties of particleboards glued with ester-modified PF resin

Tabela 4. Wpływ temperatury prasowania na właściwości płyt wiórowych zaklejanych żywicą PF modyfikowaną estrami

Type of modifier Rodzaj modyfikatora	Pressing temperature Temperatura prasowania °C	Swelling Spęcznienie %		V-100 N·mm^{-2}		IB N·mm^{-2}		MOR N·mm^{-2}		MOE N·mm^{-2}	
Control board Płyta kontrolna	180	29.5	*5.3*	0.40	*0.08*	0.52	*0.13*	15.3	*2.1*	2 520	*360*
Ethylene glycol diacetate Dioctan etylenu	160	25.2	*4.7*	0.30	*0.08*	0.46	*0.05*	18.9	*2.2*	2 760	*360*
	170	24.1	*3.7*	0.64	*0.15*	0.92	*0.13*	21.7	*3.6*	3 100	*450*
	180	22.3	*5.2*	0.86	*0.15*	1.27	*0.13*	23.7	*2.8*	3 450	*310*
	190	22	*2.2*	0.86	*0.11*	1.25	*0.11*	25.3	*2.2*	3 480	*350*
	200	22.1	*1.8*	0.94	*0.09*	1.29	*0.14*	22.2	*1.8*	3 360	*310*
Propylene glycol diacetate Dioctan propylenu	160	28.2	*4.1*	0.35	*0.07*	0.44	*0.06*	17.4	*3.9*	2 700	*380*
	170	25.7	*4.3*	0.64	*0.08*	0.82	*0.09*	22.1	*2.8*	3 130	*250*
	180	24.1	*3.9*	0.88	*0.23*	1.25	*0.18*	23.4	*1.6*	3 280	*380*
	190	24.4	*2.3*	0.86	*0.08*	1.25	*0.16*	23.7	*1.8*	3 190	*220*
	200	23.4	*1.9*	0.87	*0.06*	1.27	*0.17*	24.1	*1.1*	3 390	*360*

Standard deviation – italics.
Odchylenie standardowe – italiki.

the respective standard (0.45 and 0.15 according to EN 312-5). Such levels of mechanical properties of manufactured boards may thus show that applied modifiers accelerate resin curing, thus facilitating the production of particleboards with good mechanical properties at a reduced pressing temperature. It also needs to be stressed that increasing pressing temperature above 180°C generally does not result in a further improvement of properties of manufactured boards. As it results from the conducted tests (Table 4) properties of boards produced under these conditions are similar to those of boards manufactured at 180°C.

CONCLUSIONS

1. The introduction of diol esters to liquid PF resin results in an increase in its reactivity, manifested by a shortening of gelation time and a deterioration of its pot life at 20ºC.

2. Modification of PF resin with diol esters makes it possible to produce particleboards with improved properties in comparison to the control board.

3. The application of such modified resin also facilitates the production of particleboards meeting the requirements of the respective standard at a reduced temperature or shortened pressing time.

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WŁAŚCIWOŚCI PŁYT WIÓROWYCH ZAKLEJANYCH ŻYWICĄ PF MODYFIKOWANĄ ESTRAMI ALKOHOLI DIWODOROTLENOWYCH

Streszczenie. W pracy zbadano właściwości płyt wiórowych zaklejanych żywicą PF modyfikowaną estrami alkoholi diwodorotlenowych. Jako modyfikatory zastosowano dioctan etylenu i propylenu w ilościach od 0,01 do 0,05 mola na 100 g s.m.ż. Przeprowadzone badania wykazały, iż modyfikacja żywicy PF tego rodzaju estrami pozwala, przy zachowaniu identycznych parametrów prasowania, na wytworzenie płyt wiórowych o lepszych właściwościach mechanicznych i podwyższonej wodoodporności w porównaniu z płytą kontrolną zaklejaną czystą żywicą PF. Ponadto zastosowanie estrów alkoholi diwodorotlenowych jako modyfikatorów żywicy fenolowej umożliwia, w obniżonej temperaturze lub skróconym czasie prasowania, wytworzenie płyt wiórowych o dobrych właściwościach mechanicznych i dużej wodoodporności. Natomiast nie zaobserwowano istotnych różnic właściwości płyt w zależności od rodzaju alkoholu diwodorotlenowego tworzącego ester.

Słowa kluczowe: żywica PF, estry, płyta wiórowa

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