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PROPERTIES OF PARTICLEBOARDS RESINATED WITH PMDI RESIN MODIFIED WITH ETHYLENE GLYCOL AND PEG 300

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SYNOPSIS. The study investigated the effect of ethylene glycol and polyethyleneglycol PEG 300, as well as the effect of the method of their introduction to the particle and resin mixture on the properties of particleboards resinated with PMDI resin. The conducted investigations showed that PMDI resin modification with ethylene glycol or PEG 300 results in an increase in physical and mechanical properties of manufactured boards, such as internal bond, rigidity, as well as absorbability and swelling in thickness. In turn, the application of polyols onto particles in the amounts up to 0.015 moles in relation to particle dry weight results in an improvement of physical and mechanical properties of particleboards, although the introduction of polyols in the amounts exceeding this value caused a deterioration of their properties. Particleboards with the best physical and mechanical properties may be obtained thanks to the introduction to PMDI resin of polyols in the amount of 0.02 moles in relation to resin dry weight.

KEY WORDS: PMDI resin, particleboards, modification, polyols

INTRODUCTION

Production of particleboards resinated with PMDI resins has been developing quite rapidly in recent years. It results from studies conducted so far that boards resinated with PMDI resin exceed in terms of their properties boards resinated with phenolic or amino resins. For this reason further development of production of particleboards resinated with isocyanates requires a special attention. Studies on the feasibility of the application of isocyanate resins to manufacture wood-based materials are being carried out both aiming at the reduction of their application costs (Leitheiser and Johns 1983, Sellers 1989, Pizzi and Walton 1992, Pizzi et al. 1993, Miller et al. 2002, Simon et al. 2002), and their modification to manufacture resins applicable in the production of new types of wood-based materials, requiring resins with even better properties. Promising results were obtained using polyols for this purpose. It results from the conducted studies that

on the one hand polyols increase the potential to form cross-linkage between chains of isocyanate polymers, causing higher cross-linking of such resin. On the other hand, some polyols may result in increased plasticity of PMDI resin, thus causing its better spreading on the surface of the resinated material (Milota and Wilson 1985). Hence it needs to be expected that an increase in cross-linking and plasticity of the resin will result in improved strength of the resinated material.

For this reason the aim of this study was to investigate the effect of ethylene glycol and polyethylene glycol PEG 300, and the method of their introduction to the particle-resin mixture on the properties of particleboards resinated with PMDI resin.

MATERIAL AND METHODS

Polyisocyanate resin with the brand name of LUBRANAT M 20 FB, modified with ethylene glycol and polyethylene glycol PEG 300, was used to resinate wood particles.

Single-layer particleboards with the density of 700 kg/m^3 and dimensions of 600 × 500 × 12 mm were manufactured under laboratory conditions from pine chips, applying the following pressing parameters:

– pressing time 5 min,
– unit pressure 2.5 MPa,
– temperature 200°C,
– resination rate 8%.

Pressing of produced particleboards was applied in two variants. In the first variant chips were resinated with PMDI resin modified with glycol and polyethylene glycol PEG 300 in the amounts of 0.01, 0.015, 0.02 and 0.025 moles per 100 g dry weight of resin. In turn, in the other variant glycol and polyethylene glycol PEG-300 were added onto chips before the process of their resination with PMDI resin, in the amounts of 0.01, 0.015, 0.02, 0.025 and 0.05 moles per 100 g dry weight of chips, respectively. In both variants pressing parameters were identical.

Properties of the manufactured boards were tested according to respective standards:

– 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

The effect of modifier amounts and introduction methods on properties of particleboards

Testing results of the effect of the amounts and introduction methods of ethylene glycol and PEG 300 as modifiers of PMDI resin in the process of manufacturing particleboards on the properties of produced boards are presented in Tables 1 and 2.

Table 1. The effect of amounts of ethylene glycol and PEG 300 introduced to PMDI resin on physical and mechanical properties of particleboards
Tabela 1. Wpływ ilości glikolu etylenowego i PEG 300 wprowadzanych do żywicy PMDI na fizyczne i mechaniczne właściwości płyt wiórowych

Kind of modifier Rodzaj modyfikatora	Amount, mole/ 100 g d.r.s. Ilość, mol/ 100 g s.m.ż.	Properties – Właściwości					
		IB	MOR	MOE	V-100	swelling spęcznienie	absorbability nasiąkliwość
		MPa				%	
PMDI		0.86	20	3 220	0.47	19	67
		7.1*	9.1	10.0	8.8	8.9	10.6
Ethylene glycol Glikol etylenowy	0.01	1.02	19	3 050	0.69	18	61
		6.9	8.9	10.1	9.2	11.2	9.9
	0.015	1.08	21	3 070	0.68	19	63
		7.6	10.2	9.8	10.1	10.9	11.3
	0.02	1.07	23	3 320	0.60	16	58
		8.3	9.8	9.8	9.6	6.9	8.9
	0.025	0.94	19	3 090	0.59	18	61
		9.0	9.9	9.6	7.8	9.1	9.2
PEG 300 Polietyleno--glikol 300	0.01	1.16	19	3 030	0.66	18	68
		8.6	9.3	10.2	9.1	11.2	10.8
	0.015	1.20	19	2 960	0.63	17	66
		9.2	9.4	9.6	9.9	9.8	10.8
	0.02	1.27	20	2 740	0.60	16	63
		8.9	9.8	9.6	7.8	9.3	10.6
	0.025	1.09	20	2 180	0.57	20	77
		10.1	9.6	8.9	8.6	9.7	9.9

*Variation coefficient.
*Współczynnik zmienności.

It results from the conducted investigations that the introduction to the resin of both glycol and PEG 300 in the amounts up to 0.02 moles caused an improvement of strength properties proportional to the amount of the applied modifier (Table 1). Thus, if internal bond increases by a maximum of 24% in case of glycol, the addition of PEG 300 causes its increase by as much as 48%. In contrast, the observed decrease in internal bond for both modifiers introduced in the amount of 0.025 moles in relation to 100 g dry weight of resin might have been caused

Table 2. The effect of amounts of ethylene glycol and PEG 300 applied onto chips on physical and mechanical properties of particleboards resinated with PMDI resin
Tabela 2. Wpływ ilości glikolu etylenowego i PEG 300 nanoszonych na wióry na fizyczne i mechaniczne właściwości płyt wiórowych zaklejanych żywicą PMDI

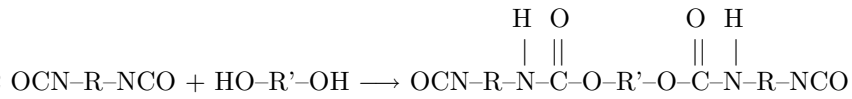
Kind of modifier Rodzaj modyfikatora	Amount, mole/ 100 g d.r.s. Ilość, mol/ 100 g s.m.ż.	Properties – Właściwości					
		IB	MOR	MOE	V-100	swelling spęcznienie	absorbability nasiąkliwość
		MPa				%	
PMDI		0.86	20	3 220	0.47	19	67
		7.1*	9.1	10.0	8.8	8.9	10.6
Ethylene glycol Glikol etylenowy	0.01	1.06	22	3 540	0.65	17	66
		8.8	10.1	12.3	9.4	10.1	9.6
	0.015	1.11	24	3 990	0.68	18	68
		8.9	9.8	11.9	9.6	9.8	9.8
	0.02	0.94	20	3 750	0.26	14	63
		9.2	9.8	10.8	15.8	12.3	10.6
	0.025	0.68	14	3 380	0.03	12	63
		9.6	10.6	9.9	18.9	11.1	10.2
	0.05	0.51	11	3 030	–	12	55
		10.1	11.2	9.8		11.6	9.9
PEG 300 Polietyleno--glikol 300	0.01	1.00	21	3 830	0.68	20	66
		11.1	10.2	10.2	10.5	9.6	8.9
	0.015	1.02	23	3 460	0.65	21	67
		11.6	9.9	9.9	9.6	9.6	9.9
	0.02	0.86	16	2 940	0.53	22	68
		10.2	10.6	10.6	8.6	10.4	11.9
	0.025	0.77	11	2 300	0.14	26	70
		9.9	10.8	11.3	9.4	11.5	12.6
	0.05	0.47	8	1 710	0.08	27	71
		10.5	11.8	11.6	12.8	11.0	11.1

*Variation coefficient.
*Współczynnik zmienności.

by the fact that as a result of excessive polyol concentration PMDI resin reacted primarily with hydroxyl groups coming from polyols, instead of hydroxyl groups of wood. A consequence of this fact is the formation of a lower number of polymer--wood bonds, which results in a deterioration of strength properties (Milota and Wilson 1985). However, the strength of such boards, even at maximum amounts of modifiers, is higher than the strength of the control board.

The applied polyols had a less pronounced effect on modulus of rupture (Table 1). In this case the maximum increase in strength, which was found for boards with the addition of 0.02 moles, was 15% for ethylene glycol. In contrast, the modulus of elasticity decreased, generally along with the increase in the amount of added modifier. The highest drop in the modulus, by as much as 1040 MPa, was observed for PEG 300 introduced in the maximum amount of 0.025 moles. Results of these investigations confirm previous reports (Milota and Wilson 1985) that polyols increase the plasticity of PMDI resin as a result of methylene bridges

($-CH_2-$) embedded in its structure, in accordance with the reaction:



while the longer the alkyl chain of polyol R', the more plastic the resin is.

Among strength properties an important one for water-resistant boards is tear resistance after the boiling test (V-100), determining the usability of the material under increased humidity conditions. Generally it may be said that the addition of both ethylene glycol and PEG 300 to PMDI resin results in a considerable, on average by approx. 33%, increase in their strength measured by this parameter (Table 1). Although the obtained values show a slight decreasing trend along with the increase in their amounts introduced to resin, eve for maximum amounts they considerably exceed the value defined by the respective standard (0.15 MPa according to PN EN 312-5).

In turn, it may be concluded from the results of tests on absorbability and swelling in thickness after 24 h presented in Table 1 that the applied modifiers do not have a significant effect on these properties of manufactured boards. A slight increase in hydrophobic properties is only observed, manifested in a decrease in swelling in thickness (by approx. 16%) for the addition of both modifiers in the amount of 0.02 moles.

The trends are quite different for properties of particleboards in case of spreading ethylene glycol and PEG 300 directly onto chips prior to their resination with PMDI resin (Table 2). It results from the investigations in this respect that the application of modifiers directly onto chips in the amounts up to 0.015 moles in relation to 100 g dry weight of chips results in an increase in strength properties of manufactured particleboards. Under such conditions for example an increase in internal bond by 29 and 19% and bending strength by 20 and 15% was observed for ethylene glycol and PEG 300, respectively. In turn, water resistance measured by tensile strength after the boiling test exceeded considerably, on average by 0.30 MPa, the value obtained for the control board. Further increase in the amounts of modifiers applied onto chips caused a considerable deterioration in strength properties of manufactured boards (IB, MOR and V-100). It may be explained by the fact that polyols applied onto chips block hydroxyl groups, resulting in the formation of a smaller number of resin-wood bonds in the process of pressing, which causes a decrease in strength. Such a line of reasoning may be also confirmed by the results of tests on swelling in thickness and absorbability of particleboards in case when PEG 300 is applied onto chips. Then, as a result of the formation of a lower number of resin-wood bonds, penetration of water inside boards is facilitated and thus the increase in the hydrophilic properties of particleboards, observed in that case, was manifested in increased absorbability and swelling in thickness by 6 and 42%, respectively, for the maximum amount of the modifier.

CONCLUSIONS

1. Modification of PMDI resin with ethylene glycol or PEG 300 causes an increase in the physical and mechanical properties of manufactured boards, such as internal bond and modulus of rupture. In turn, the modulus of elasticity decreases in connection with an increase in plasticity of the modified resin.
2. Water resistance of tested boards, measured by their tear resistance after the boiling test, irrespective of the amounts of applied modifiers, is very high and considerably exceeds requirements specified in the respective standard.
3. Application onto chips of polyols in the amounts up to 0.015 moles in relation to 100 g dry weight of chips results in an increase in physical and mechanical properties of particleboards; however, introduction of polyols in even bigger amounts results in a deterioration of board properties.
4. Particleboards exhibiting the best mechanical properties and considerably improved water resistance may be obtained by the introduction to PMDI resin of polyols in the amount of 0.02 moles in relation to dry weight of resin.

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WŁAŚCIWOŚCI PŁYT WIÓROWYCH ZAKLEJANYCH ŻYWICĄ PMDI MODYFIKOWANĄ GLIKOLEM ETYLENOWYM I PEG 300

Streszczenie

W pracy zbadano wpływu glikolu etylenowego i polietylenoglikolu PEG 300 oraz sposobu ich wprowadzania do mieszaniny wiórowo-klejowej na właściwości płyt wiórowych zaklejanych żywicą PMDI. Przeprowadzone badania wykazały, iż modyfikacja żywicy PMDI glikolem etylenowym bądź PEG 300 powoduje wzrost fizycznych i mechanicznych właściwości wytworzonych płyt, takich jak: wytrzymałość na rozciąganie prostopadłe do płaszczyzn płyty, zginanie statyczne oraz nasiąkliwość i spęcznienie. Nanoszenie natomiast na wióry polioli w ilości do 0,015 mola w stosunku do suchej masy wiórów powoduje wzrost fizycznych i mechanicznych właściwości płyt wiórowych, jednakże wprowadzanie polioli powyżej tej ilości powoduje pogorszenie ich właściwości. Płyty wiórowe charakteryzujące się najlepszymi fizycznymi i mechanicznymi właściwościami można otrzymać przez wprowadzanie do żywicy PMDI polioli w ilości 0,02 mola w stosunku do suchej masy żywicy.

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