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Effect of addition of titanium dioxide and talc on properties of phenolic resin and water-resistant plywood

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Abstract: *Effect of addition of titanium dioxide and talc on properties of phenolic resin and water- resistant plywood.* This work presents a potential substitution of titanium dioxide with talc in the process of colour lightening in glue line of PF resin in a water-resistant plywood. Within the scope of the research, the brightening degree was determined for the samples of cured resins according to the model CIE L*a*b*, the influence of substitution of TiO_2 with talc upon properties of adhesive mixture and physico-mechanical properties of plywood were investigated. The conducted research shows that the optimum level of substituting talc for TiO_2 is 25%, which makes it possible to produce water-resistant plywood with required properties and bright colour of the glue line.

Keywords: plywood, colour of glue line, titanium dioxide, talc

INTRODUCTION

The present work is a continuation of research in the field of colour lightening in glue line of PF resin, through the introduction of titanium dioxide (TiO_2) and its substitutes in the form of white mineral fillers to the adhesive resin. Conducted so far studies have shown that it is possible to manufacture plywood with a considerable bleaching rate of PF resin glue line, bond quality and strength required by the respective standard for exterior plywood with use TiO_2, and chalk or barite (Dukarska and Łęcka 2007, 2008, 2009, Dukarska et al. 2010, 2011). The amount of TiO_2 required to lighten the colour of glue line made from PF resin was determined on the basis of preliminary analyses to be 4.0 parts by weight/100 parts by weight of PF resin (Dukarska et al. 2009). It was also found that the optimal degree of substituting chalk and barite for TiO_2 should not exceed 50 and 25 % adequately. Introduction of such an amount of white mineral fillers to the adhesive mixture containing TiO_2 results in an increase of optical properties of glue lines and at the same time it does not affect physico-mechanical properties of manufactured water-resistant plywood.

From a review of literature concerning the use of white mineral fillers has been found that the pigmenting properties and a wide range of applications has also magnesium hydroxysilicate, so-called talc (Leong et al. 2004, Zhou and Mallick 2005). Talc is characterised by high brightness, good wettability, poor tendency for agglomeration, stability at high temperatures, improved barrier properties and resistance to the action of water, atmosphere or acid. Moreover, its price is relatively low. For these reasons, talc is used as a filler in paint, paper, plastic, food and pharmaceuticals industry and in other industrial applications.

Therefore, the aim of the present work was to investigate the possibility of applying talc as a substitute for TiO_2 in order to brighten the colour of glue line of water-resistant plywood manufactured with use of PF resin. Moreover, the effect of applied additives on mechanical properties and bond quality of manufactured plywood was investigated.

MATERIALS AND METHODS

For the research purposes, PF resin was applied in manufacturing of water-resistant plywood,. As a colouring agent, rutile titanium dioxide and talc (chemical formula $Mg_3(OH)_2Si_4O_{10}$) were used. Their properties are shown in |Table 1. In order to stabilize solid

particles of pigment and filler as well as to regulate viscosity of the adhesive mixture as an assistant

Tab. 1 Characteristics of TiO_2 and talc

TiO_2		Talc	
Parameter	**Value**	**Parameter**	**Value**
TiO_2 content	93%	MgO content	31%
Content of water-solublesubstances	0.03%	SiO_2 content	60%
Content of volatile substances	0.5%	Oil absorption number	30g/100g
pH of water solution	6.5 – 8.0	pH of water solution	9.10
Sediment on 0.045 mm screen	0.01%	Apparent density	0.50 g/cm^3
Covering power	26 g/m^2	Brightness	92%
Whiteness	93.5%	Whiteness	80%

was used flame silica at 1.0 p.b.w./100 p.b.w. of PF resin. Reference resin mixtures containing only mimosa filler (UT-10) were prepared according to technological formulations. The composition of the compound resin as well as the preparation method were determined on the basis of earlier investigations (Dukarska and Łęcka 2008, 2009, 2011). The amount of TiO_2 required to lighten the colour of glue line made from PF resin was 4.0 parts by weight/100 parts by weight of PF resin (Dukarska et al. 2009). In order to determine the optimum proportion of talc in PF resin dyeing a 25; 50; 75 and 100% substitution of titanium dioxide with talc was applied.

The degree of lightening of glue line colour was evaluated on the basis of measurements taken of colour parameters in samples cured with adhesive mixtures in the CIE L*a*b* system with the use an Elrepho apparatus at a wavelength of 457 nm. Based on the values of components L*, a* and b* the mean value of colour shift ΔE was established (according to the equation described in the work Dukarska et al. 2011). The ΔE value determines total difference in colour caused by a gradual substitution of TiO_2 with talc.

Additionally, for the optimum composition of adhesive mixture, its viscosity at 20^{o}C and the activation energy of the curing process based on DSC analyses according to Kissinger and Ozawa were determined.

Experimental plywood was manufactured in the three-layer system from birch veneers with a thickness of 1.4×1.7×1.4 mm, applying the following pressing parameters: temperature 135^{o}C, unit pressure 1.6 N/mm^2 and time 4 min. Adhesive mixtures were spread on veneer sheets at 160 g/m^2. Manufactured plywood was subjected to analysis of bond quality by determining shear strength of the adhesive-bonded joint (f_v) and the proportion of shear area in wood (U) by tests verifying their water resistance. These tests were performed according to the EN 314-2, required for bond quality grade 3 gluability, typical of exterior plywood. Preparation treatments and the determination of bond quality in the shear tests were conducted following the standard EN 314-1.

RESULTS AND DISCUSSION

Results of investigations upon the possibility of brightening the PF resin glue line by means of applying TiO_2 and talc to the resin are shown in Table 2. The presented data shows clearly that a gradual substitution of talc filler for TiO_2 results in the decrease of the chromatic component L* and the increase of chromatic components a* and b*, which means a decline in brightness and a further growth in the amount of red and yellow. Substituting talc for TiO_2 in range 25-50% results in obtaining such a saturation degree of yellow and red which is comparable with parameters of the compound resin containing only TiO_2. However, the visual evaluation of the investigated samples and the average value of colour shift ΔE indicate that

the optimal degree of substituting talc for TiO_2 should not exceed 25%. Further increase of the amount of talc leads to a gradual and significant growth of ΔE and, at the same time,

Tab. 2 The effect of the composition of adhesive mixtures upon the brightness degree of their colour

Amount of TiO_2 [pbw]	Amount of talc [pbw]	L*	a*	b*	ΔE
PF		21.05	6.02	6.01	-
4.0	**-**	**76.26**	**5.63**	**31.28**	**-**
3.0	**1.0**	74.22	4.15	31.90	1.73
2.0	**2.0**	70.78	5.64	33.39	3.50
1.0	**3.0**	66.09	7.33	34.80	8.44
0.0	**4.0**	55.23	11.25	38.96	20.66

decline in brightness and increase of the saturation of red colour. The analysis of these values, exclude the possibility of total substitution of TiO_2 with talc.

Applying talc as a substitute for TiO_2 in designated amount, the value of activation energy of curing adhesive mixture is comparable to mixture containing a commercial filler. These values, estimated according to Kissinger and Ozawa, are respectively: 54.53 kJ/mol and 58.44 kJ/mol of the resin with the addition of the mimosa filler and 56.28 kJ/mol and 60.11 kJ/mol with addition of TiO_2 and talc. Figure 1 shows changes of adhesive mixtures viscosity in time at a temperature 20ºC. The reference mixture did not show significant changes in viscosity up to 4 h, while the resin with addition of TiO_2 and SiO_2 was characterised by gradual increase in viscosity. Substituting talc for TiO_2 results in further increase in viscosity of adhesive mixture. As in previous studies, the simultaneous introduction of TiO_2 and talc to PF resin leads to significant increase in the viscosity of the adhesive mixture. Immediately after preparation, the viscosity of the mixture containing talc was 30% higher than the reference mixture. Viscosity reached after 4 h was by 60% higher than the reference mixture and by 30% higher than mixture containing only TiO_2 and SiO_2. This fact can be explained by a significant density of the talc and thus its tendency to sedimentation of their particles in adhesive resin solution.

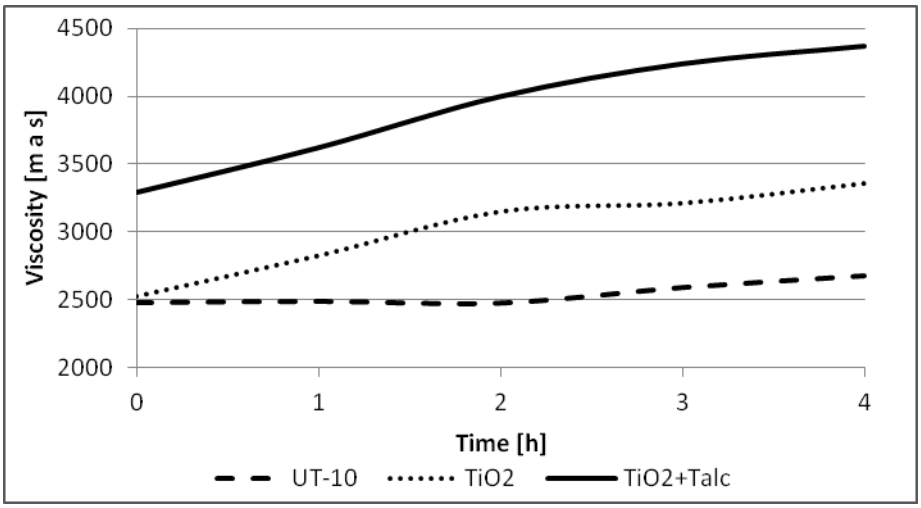

Fig.1 Time changes of viscosity in adhesive mixtures depending on their formulations

Table 3 presents the results of tests on the bonding quality of the manufactured plywood determined on the basis of shear resistance (f_v) and shear fraction. The high values

of shear resistance obtained after water-resistance tests (24h of soaking in water and a double boiling test) significantly exceed the value required by EN 314-2, i.e. 1.0 N/mm^2. It means that the manufactured plywood can be classified as class 3 bonding quality. The analysis of values of the shear resistance shows that substituting white pigment with talc results in a increase of water-resistance of tested plywood determined after double boil test. In relation to control plywood the shear resistance increased by 20% and compared to plywood produced with only TiO_2 it involved more than 10%. The obtained average values of shear fraction in wood do not indicate a clear relation between the percentage fraction of destruction in the glue line and the composition of the compound resin. An analogous conclusions were obtained in earlier studies that used other white fillers, such as chalk and barite (Dukarska et al. 2010, 2011).

Tab. 3 Bonding quality of plywood depending on the composition of adhesive mixtures

No.	Composition of adhesive mixtures [pbw/100 pbw of PF resin]				f_v [N/mm^2]		Shear fraction [%]	
	UT-10	SiO_2	TiO_2	Talc	Soaking	Boiling	Soaking	Boiling
1.	14	-	-	-	1.92	1.47	40	30
2.		1	4	-	1.91	1.64	30	35
3.			3	1	1.90	1.78	40	40

Mechanical property of plywood manufactured with the share of talc were determined on the basis of their bending strength (f_m) and modulus of elasticity (E_m) along and across the fibres of face layers. Their results are presented in Table 4. Analysis of data does not show significant differences, which means that introducing TiO_2 and talc as its substitute into adhesive mixture does not affect the mechanical properties of the manufactured plywood.

Tab. 4 Bending strength and modulus of elasticity of plywood depending on the composition of adhesive mixtures

No.	Composition of adhesive mixtures [pbw/100 pbw of PF resin]				f_m [N/mm^2]		E_m [N/mm^2]	
	UT-10	SiO_2	TiO_2	Talc	$\parallel$	$\perp$	$\parallel$	$\perp$
1.	14	-	-	-	147	41.4	15 300	1 770
2.		1	4	-	142	43.4	15 300	2 200
3.			3	1	143	40.0	14 950	1 810

CONCLUSION

The conducted investigations show that it is possible to use titanium dioxide and talc in order to manufacture water-resistant plywood with a brighter colour of PF resin glue line. The optimal degree of substituting talc for TiO_2 should not exceed 25%. Introduction of such an amount of talc to the adhesive mixture does not cause significant changes in optical properties of glue lines, reactivity of adhesive mixture and physico-mechanical properties of manufactured plywood. Tested adhesive mixture containing TiO_2 and talc, despite a significant increase in viscosity showed suitability for the resination process.

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Streszczenie: *Wpływ dodatku TiO_2 oraz talku na właściwości żywicy fenolowej oraz sklejki wodoodpornej.* Prezentowana praca stanowi kontynuacje badań w zakresie rozjaśniana barwy spoiny klejowej z żywicy PF za pomocą pigmentu bieli w postaci TiO_2 oraz białych wypełniaczy nieorganicznych. W pracy przedstawiono możliwość zastosowania talku jako częściowego substytutu TiO_2 do rozjaśniania barwy spoiny klejowej z żywicy PF sklejek wodoodpornych. W ramach przeprowadzonych badań określono stopień rozjaśnienia barwy utwardzonych mieszanin klejowych wg. modelu CIE L*a*b* oraz wpływ dodatku talku do mieszaniny klejowej na jej podstawowe właściwości, barwę spoiny klejowej oraz na fizyko-mechaniczne właściwości wytworzonych sklejek. Na podstawie uzyskanych wyników badań ustalono, iż optymalny stopień substytucji TiO_2 talkiem wynosi 25%, co pozwala na wytworzenie sklejek o wymaganych właściwościach i znacznie rozjaśnionej barwie spoiny klejowej.

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