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The effect of an addition of nano-SiO_2 to urea resin on the properties of boards manufactured from rape straw

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Abstract: *The effect of an addition of nano- SiO_2 to urea resin on the properties of boards manufactured from rape straw.* In the present work, we investigated the physical and mechanical properties of rape boards depending on the amount of nano-SiO_2 added to the UF resin. The results of study indicate that the introduction of nano-SiO_2 to UF resin, significantly improves the strength and hygiene of the boards produced from rape straw. It was found that the optimum amount of nano-SiO_2 allowing such improvement is 1.5% nano-SiO_2/100g d.m. of UF resin.

Keywords: rape boards, nano-SiO_2, urea - formaldehyde resin

INTRODUCTION

In the wood based materials industry, a commonly used adhesive resin is a urea - formaldehyde. Its advantages are high reactivity, lack of color, low cost and ease of use. The major disadvantages of UF resin are low water resistance and emission of significant amounts of formaldehyde. For this reason, this resin is usually used for the manufacture of wood-based materials intended for interior use. Research conducted by the author of this work and other (Dukarska et al. 2009, Lin et al. 2006, Roumeli et al. 2012) revealed that the introduction of synthetic silica with nanoscopic molecule dimensions to urea – formaldehyde resin results in enhancement of the mechanical properties of wood based materials especially their internal bond, modulus of rupture and hygienic. At the same time it has been proven that nano-SiO_2 does not significantly affect the curing time of the resin, and there is not necessary to change the press conditions (Lin et al. 2006). Addition nano-SiO_2 do not have an effect in the thermal stability of the resin (Roumeli et al. 2012). Considering this, the research was undertaken on the possibility of improving the properties of boards made of rape straw particles by introducing an optimal amount of nano-SiO_2 to the UF resin. It was revealed, in so far conducted numerous studies, that rape straw may constitute a valuable substitute for wood chips in particle boards manufacturing on condition that relevant type or quantity of binder is applied (Dukarska et al. 2006, Keyhole et al. 2005; Pałubicki et al. 2003). It was also shown that in order to obtain sufficiently high properties of boards of rape straw glued with UF resin, there must be either used gluing degree of 12% to 14% or the substitution of wood chips by rape straw particles must be reduced.
Thus, the aim of this study was to investigate the effect of an addition of nano-SiO_2 to urea – formaldehyde resins on properties of boards manufactured from rape straw particles.

MATERIAL AND METHODS

Boards were manufactured using particles of rape straw with urea-formaldehyde resin (UF) as binding agent. It had the following characteristics: dry resin solids – 64.5%, density - 1.290 g.cm^{-3}, miscibility with water – 1.6, viscosity – 640 mPa s, gelation time at 100°C - 95 s, pH – 7.9. The hydrophilous fumed silica (nano-SiO_2) with specific surface 200±25 m^2/g was added to the resin in the amounts 0; 0.5; 1.0; 1.5 and 2.0 % per 100 g dry mass of resin.

To increase the chemical affinity of nano-SiO_2 to the adhesive resin components, the silica particles were subjected to surface modification by the coupling agent. The research of Lin et al. (2006) has shown that, the most optimal UF resin coupling agent for the surfaces of

nano-SiO_2 is 3-aminopropyltriethoxysilane of the formula $NH_2(CH_2)_3Si(OC_2H_5)_3$. This agent, having two different functional groups, reduces the surface energy of the nanoparticles of SiO_2, and thus improves the chemical activity to the UF resin. The modification of silica was carried out according to the method Domka et al. (1996) mechanically stirring at the speed of 1000 r/min.

In the production of boards there were used rape straw particles, obtained as a result of double shredding at a knife shredder. In order to determine the effect of an addition of nano-SiO_2 to urea resin on the properties of rape boards the single-layer straw boards with a thickness of 12 mm and density of 700 kg/m^3 were manufactured on a semi-commercial scale, applying the following parameters: pressing time - 22 s/mm of board thickness, unit pressure - 2.5 N/mm^2, temperature - 200^{o}C, resination rate - 12%

In the manufactured boards, after a 7-day conditioning period, the following properties were determined:

- modulus of rupture (MOR) and modulus of elasticity (MOE) according to EN 310
- internal bond (IB) according to EN 319
- swelling in thickness (G_t) and additionally absorbability (W_n) after 24h soaking in water according to EN 317
- free formaldehyde content using the perforation test according to EN 120

In the results analysis as the reference sample, the rape boards resinated with UF resin without an addition of nano-SiO_2 have been used.

DISCUSSION OF RESULTS

The results of studies upon the physical and mechanical properties of rape boards depending on the amount of nano-SiO_2 added to the UF resin are shown in Figure 1 and Table 1. Reference board formed without the nano-SiO_2 has a low internal bond perpendicular to the plane (IB) which is lower than the value required by the standard EN 312. As shown in Figure 1, introducing a small amount of fumed silica of nanoscopic particle size to the gluing resin (in the range 1.0-1.5%/100 g d.m of resin), causes a significant increase in the board internal bond (up to 68%) in relation to the reference board.

The increase is significant enough that the boards made with 1.0% addition of silica can be classified as P1 type i.e. according to standard EN 312 they are a general purpose boards for use in dry conditions. Increasing the amount of nano-SiO_2 above 1.5% causes a decrease of the IB to the value comparable to the reference board. Also, addition of considered amount of nano-SiO_2 to a gluing resin has affected positively bending strength (MOR) and modulus of elasticity (MOE) of the surveyed rape boards (Table 1). MOR value at 1.5% addition of nano-SiO_2 was increased by approximately 25%, and the MOE by about 13%. The results show that the introduction of modified nano-SiO_2 to UF resin increases the mechanical properties of particleboard, plywood and MDF (Lin et al. 2006) as well as properties of boards made from waste particles of annual plants such as rape straw.

Differently is shaped water resistance of tested boards, determined by swelling and water absorption after 24 h soaking in water. It was noted a decrease in their water resistance, particularly in water swelling and a little in water absorption. The data in Table 1 shows that the introduction of nano-SiO_2 in an amount of 1.5% results in an increase of swelling up to 30% and absorption by approximately 10%.

As in Lin et al. (2006) studies in boards prepared with 1.0 and 1.5% addition of nano-SiO_2 was observed a slight decrease in the content of free formaldehyde determined by the perforator method. Increasing additive nano-SiO_2 to the gluing resin above 1.5% does not affect the further reduction of free formaldehyde content. Undoubtedly, the increase in strength and hygienic of the boards results from the presence on the functional groups on the silica surface capable of reacting with components of the UF resin and thereby enhancing

their performance. In addition, a positive effect on the hygienic has also significantly expanded surface area of the nano-SiO_2 - of 200 m^2/g - capable of free formaldehyde absorption.

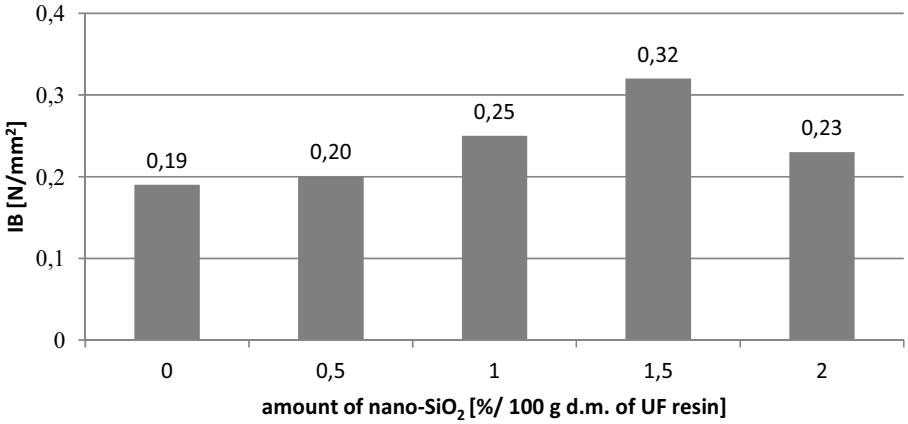

Fig.1 Internal bond of rape boards depending on amount of nano-SiO_2 added to UF resin

Tab. 1 Selected properties of rape boards depending on amount of nano-SiO_2 added to UF resin

Amount of nano-SiO_2	**MOR**		**MOE**		**G_t**		**W_n**		**CH_2O**
%/100 g d.m. of resin	N/mm^2				%				mg/100 g d.m. of board
0	12.8	*2,02**	2 590	*250*	32.6	*2,3*	81.2	*1,9*	9.2
0.5	12.3	*1,70*	2 480	*180*	33.9	*1,4*	85.8	*4,3*	6.5
1.0	13.2	*1,31*	2 800	*290*	30.5	*4,4*	80.2	*3,9*	5.8
1.5	15.9	*2,00*	2 930	*140*	42.4	*0,9*	89.4	*2,1*	6.1
2.0	14.7	*1,87*	2 890	*210*	49.3	*2,5*	92.5	*2,8*	8.7

*standard deviation

CONCLUSIONS

The performed investigations have shown that the introduction of nano-SiO_2 surface-modified with 3-aminopropyltriethoxysilane to UF resin, significantly improves the strength of the boards produced from rape straw only. The best results were obtained concerning internal bond perpendicular to the board plane. It was found that the optimum amount of nano-SiO_2 allowing a significant increase in the strength of rape boards is 1.5% nano-SiO_2/100g d.m. of UF resin. Addition of nano-SiO_2 to the gluing resin in an amount of up to 1.0% results in the improvement of the board's hygiene by reducing the free formaldehyde content. The introduction of above amounts of nano-SiO_2 to gluing resin causes decrease of water resistance especially determined by boards swelling after 24 h of soaking in water.

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Streszczenie: *Wpływ dodatku nano-SiO_2 do żywicy UF na właściwości płyt wytworzonych z słomy rzepakowej.* W niniejszej pracy przedstawiony wyniki badań płyt rzepakowych zaklejonych żywicą UF z dodatkiem różnych ilości nano-SiO_2. W ramach przeprowadzonych badań ustalono, iż wprowadzenie do żywicy UF nanocząstek SiO_2 w ilości do 1,5 %/100g s.m. żywicy powoduje wzrost wytrzymałości płyt przede wszystkim na rozciąganie prostopadłe do ich powierzchni, a także wytrzymałości na zginanie oraz moduł sprężystości. Poprawie uległa również higieniczność wytworzonych płyt.

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