ACTA FACULTATIS XYLOLOGIAE ZVOLEN, 59(2): 61−66, 2017
Zvolen, Technická univerzita vo Zvolene
DOI: 10.17423/afx.2017.59.2.06

PARTICLEBOARDS PREPARED WITH ADDITION OF COPPER SULPHATE – PART 2: MOISTURE AND STRENGTH PROPERTIES

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ABSTRACT

This work deals with selected physical and mechanical properties of the one layer particleboards (PBs) prepared with addition of biocide copper sulphate pentahydrate into melamine-urea formaldehyde glue in the amounts of 0, 2, 6, 12 or 24 w/w %. The following application properties of the copper-modified PBs were analysed – density, thickness swelling and water absorption after 2 h and 24 h, internal bond strength, bending strength – with the aim to determine whether or not they are affirming in a positive or negative sense with the used biocide. Through the linear correlations and their coefficients of determination it was found that due to a higher amount of $CuSO_4.5H_2O$ in MUF glues there significantly on 99.9% level changed only these two properties of PBs – thickness swelling after 2 hours increased ($TS_{2h} = 5.58 + 0.07 \times w/w$; $R^2 = 0.27$) and bending strength decreased ($BS = 11.39 – 0.10 \times w/w$; $R^2 = 0.49$).

Key words: particleboards, copper sulphate, swelling, water absorption, internal bond, bending strength.

INTRODUCTION

Particleboards (PBs) treated with biocides have improved biological properties – increased resistance to bacteria, fungi, etc. However, very important are also their good moisture (thickness swelling, water absorption) and mechanical (bending strength, etc.) properties. Technological principles of PB's treatment with biocides (bactericides, fungicides, insecticides, etc.) were already stated in the part 1. (REINPRECHT *et al.* 2017). For example, during the in-process treatment (IPT) of PBs, an application of biocides can be carried out in various production stages:

- impregnation of wood particles with a biocide solution,
- addition of solid (powder) or liquid (concentrate) biocide to wood particles prior to or during glue blending,
- addition of biocide to the glue or to other additives (e.g. wax),
- application of high bioactive glues,
- hot-pressing of biocide into the surface layers of PB.

Fungicides in PBs have to act against molds, blue-staining and decaying fungi, whereby they should not influence negatively their sorption, swelling and strength properties.

REINPRECHT (1996) found that due to the addition of some organic fungicides (2-tiocyanomethylthiobenzothiazole = TCMTB, tri-n-butyltinnaphtenate = TBTN) occurred only minimal changes in the thickness swelling and water absorption of the 1-layer and 3-layer PBs. In the case of protected 1-layer PBs, with the maximally used amounts of TCMTB and TBTN added into PF glue (2.5 w/w % and 12.5 w/w %, i.e. weight of active biocide per solid weight of glue in %), their 24-hour thickness swelling increased by 12.5 %, and their 24-h water absorption increased by 6.6 % and 8.3 %. The strength properties – bending strength (BS) and internal bond (IB) – of PBs protected with TCMTB and TBTN fungicides decreased approximately about 20 %. However, REINPRECHT and ŠTEFKA (1989) determined that PBs treated with sodium tetraborate ($Na_2B_4O_7.10\ H_2O$), which forms glaze on the surface of wooden particles, have a significantly worsened moisture and strength properties, mainly if this boric biocide was added to wooden particles by impregnation method than at its mixing with UF glue. Even, PBs with the maximal amount of sodium tetraborate added to wooden particles (7 w/w %, i.e. weight of active biocide per dry weight of wooden particles %) have completely disintegrated.

On contrary, TAGHIYARI and FARAJPOUR (2013) reported an improving effect of copper nanoparticles on selected physical and mechanical properties of 3-layer PBs prepared on the industrial scale. In the same time they reported reduction of the hot-press time of copper-modified PBs. Nano-copper suspension was added to the mat at 0, 100 and 150 ml/kg dry weight of wooden particles. The results showed that by addition of 100 ml nano-copper/kg wood particles the press time of PBs was shortened by 5.7 % and their BS was increased by 1.9 %. It may by concluded that a better polymerization of glues in the central layer of the mat caused by the heat-transferring property of copper nanoparticles resulted in a significant reduction of the hot-press time as well as in a partial improvement of PBs strength.

The aim of this study was to search effect of a classical inorganic biocide – copper sulphate pentahydrate ($CuSO_4.5H_2O$) added to melamine-urea formaldehyde (MUF) glue at production of 1-layer PBs – on selected biological properties (REINPRECHT *et al.* 2017), and also on selected moisture and strength properties of the copper-modified PBs.

MATERIALS AND METHODS

Particleboards treated with $CuSO_4.5H_20$

A laboratory production of the copper modified 1-layer PBs – when copper sulphate pentahydrate ($CuSO_4.5H_2O$) was added into melamine-urea formaldehyde (MUF) glues in the amounts of 0 %, 2 %, 6 %, 12 % or 24 w/w % (weight of solid copper biocide per solid weight of catalysed glue) – is described in the part 1 of the experiment.

Moisture and strength properties of copper-modified PBs

From 15 laboratory pressed PBs (360 mm × 360 mm × 16.0 mm) were prepared samples for testing the density, moisture and strength properties.

Density, moisture and strength properties of PBs were carried out in accordance with the relevant test methods as described in EN standards.

Density of PBs was determined by the Standard EN 323 (1993).

Thickness swelling (TS) and water absorption (WA) of PBs were determined after 2 and 24 hours by the Standard EN 317 (1993).

Internal bond (IB) strength, i.e. tensile strength perpendicular to the plane of the PBs, was determined by the Standard EN 319 (1993), and bending strength (BS) of PBs was determined by the Standard EN 310 (1993) – at both tests using a universal machine TiraTest 2200.

RESULTS AND DISUSSION

The moisture and strength properties of the copper-modified PBs containing copper sulphate pentahydrate ($CuSO_4.5H_2O$) are present in Tables 1 and 2, and in Figures 1 and 2.

Tab. 1 Physical and mechanical properties of the copper-modified PBs.

Properties of PBs		$CuSO_4.5H_2O$ (w/w in MUF glue)				
		0	2	6	12	24
Density	[kg·m^{-3}]	654 (10.50)	642 (11.19)	641 (17.35)	642 (21.20)	631 (14.09)
Thickness swelling (TS) after 2 h	[%]	6.25 (0.66)	5.81 (0.47)	5.27 (0.47)	5.80 (0.62)	7.45 (1.06)
Thickness swelling (TS) after 24 h	[%]	14.25 (1.14)	13.08 (0.64)	12.56 (1.19)	13.79 (1.56)	15.20 (0.93)
Water absorption (WA) after 2 h	[%]	14.28 (1.08)	13.31 (1.28)	12.77 (1.44)	13.21 (1.27)	13.83 (1.65)
Water absorption (WA) after 24 h	[%]	40.19 (2.43)	38.01 (2.43)	37.98 (2.49)	40.65 (2.18)	40.73 (3.14)
Internal bond (IB) strength	[N·mm^{-2}]	0.54 (0.08)	0.57 (0.08)	0.57 (0.08)	0.52 (0.07)	0.53 (0.06)
Bending strength (BS)	[N·mm^{-2}]	11.08 (0.79)	11.12 (0.69)	11.24 (0.87)	10.30 (0.85)	8.88 (0.92)

Notes:

- Mean values: of density from 6 samples, of TS from 9 samples, of WA from 9 samples, of IB from 12 samples, and of BS from 6 samples.
- Standard deviations are in the parentheses.

The density of the copper-modified PBs (631–642 kg·m^{-3}) was a very similar to the control PBs (654 kg·m^{-3}) – see Tab. 1. This result was confirmed as well as by a small coefficient of determination $R^2 = 0.13$ for a linear regression analysis – see Tab. 2.

Due to presence of $CuSO_4.5H_2O$ in PBs, their moisture properties did not change similarly. The thickness swelling of PBs containing the highest amount of copper biocide evidently increased about 19.2 % after 2 hours and about 6.7 % after 24 hours – see Tabs. 1 and 2, and Fig. 1. Maybe, this negative effect of copper compound could be removed by addition of a higher amount of paraffin to PBs. On contrary, changes of the water absorption of PBs were negligible – see Tabs. 1 and 2.

Copper sulphate had none effect on the internal bond strength of PBs, which always was more than 0.5 MPa – see Tabs. 1 and 2. This result is a very important for using of the copper modified PBs in practice.

Unfortunately, the bending strength of copper-modified PBs had a decreasing tendency with an increasing amount of $CuSO_4.5H_2O$ in boards ($BS = 11.39 - 0.10 \times w/w$; $R^2 = 0.49$), and maximally decreased about 19.9 % – see Tabs. 1 and 2, and Fig. 2. It means, that application of the copper-modified PBs for construction products can be limited, or their thickness should be increased.

YINGPRASERT *et al.* (2015) founded that the essential oil treatment of PBs improved their moisture properties (WA and TS), however without affecting their mechanical properties – except of a slight reduction the impact bending strength above 1.8 % due to cinnamon and clove oils. On the other hand, RANGAVAR and HOSEINY (2015) showed that addition of copper nanoparticles into the UF glue at manufacturing of PB from palm tree waste improved all their physical and mechanical properties.

Tab. 2 Linear correlation analysis of the copper sulphate pentahydrate ($CuSO_4.5H_2O$) addition into MUF glues on the properties of copper-modified PBs

	Properties of PBs	N	R	R^2	T	P	y = a + b*x
$CuSO_4.5H_2O$ (w/w in MUF glue)	Density	30	–0.36	0.13	–2.02	0.05	648.2 – 0.70*w/w
	Thickness swelling after 2 h	45	0.52	0.27	3.73	0.00	5.58 + 0.07*w/w
	Thickness swelling after 24 h	45	0.41	0.17	2.75	0.01	13.17 + 0.07*w/w
	Water absorption after 2 h	45	0.01	0.00	0.05	0.96	13.47 + 0.00*w/w
	Water absorption after 24 h	45	0.25	0.06	1.69	0.12	38.79 + 0.08*w/w
	Internal bond strength	60	–0.11	0.01	–0.84	0.40	0.55 – 0.00*w/w
	Bending strength	30	–0.70	0.49	–5.18	0.00	11.39 – 0.10*w/w

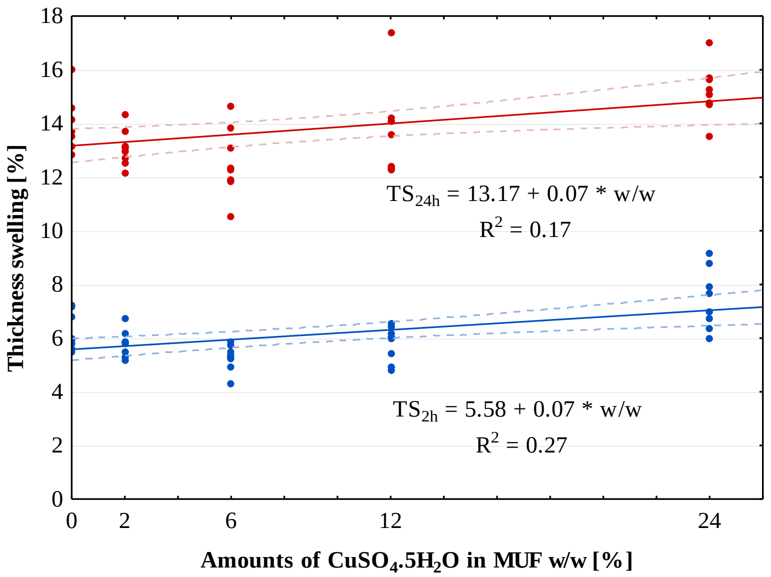

Fig. 1 Thickness swelling (TS) of the copper-modified PBs (MUF glues treated with 0 to 24 % of $CuSO_4.5H_2O$) after their 2 hours and 24 hours immersion in water.

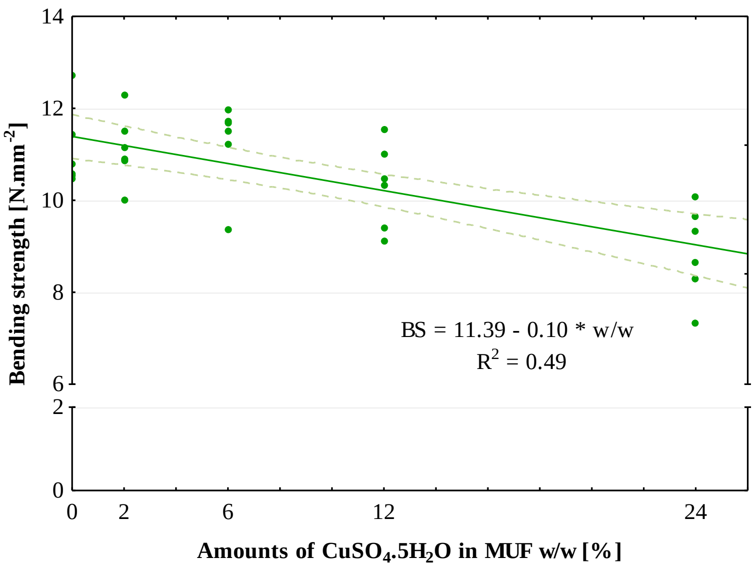

Fig. 2 Bending strength (BS) of the copper-modified PBs (MUF glues treated with 0 to 24 % of $CuSO_4.5H_2O$).

BAYATKASHKOLI *et al.* (2017) showed that strength of PBs decreased or was stable at adding selected protective substances: ACQ - alkaline copper quat, BFCA - boron-fluorine-chromium-arsenic, CTL - Chlorotalonil. The highest biological resistance was obtained for PBs made at addition of BFCA and ACQ.

CONCLUSIONS

The copper modified 1-layer PBs, due to a presence of copper sulphate pentahydrate added into melamine-urea formaldehyde glues in the amounts of 0, 2, 6, 12 or 24 w/w %, had changed some technical properties:

- thickness swelling (increased maximally about 19.2 % after 2 hours, and about 6.7 % after 24 hours),
- bending strength (decreased maximally about 19.9 %),

while other application properties of these boards did not significantly change:

- density,
- water absorption,
- internal bond strength.

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ACKNOWLEDGEMENTS

This work was supported by the Slovak Research and Development Agency under the contract No. APVV-0200-12. We thanks also to J. Rusič, V. Hyšková and M. Oros for their technical assistance.

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