Annals of Warsaw University of Life Sciences – SGGW
Forestry and Wood Technology No 73, 2011: 153-157
(Ann. WULS-SGGW, Forestry and Wood Technology 73, 2011)

Screw holding ability of the lignin-bonded biocomposites

PIOTR BORUSZEWSKI, PIOTR BORYSIUK, MARIUSZ MAMIŃSKI
Faculty of Wood Technology, Warsaw University of Life Sciences – SGGW

Abstract: *Screw holding ability of the lignin-bonded biocomposites*. Biocomposites derived from the unmodified and enzymatically modified lignin, hemp shives and shellac were manufactured in injection moulding process. The boards were characterized by hardness and screw holding ability. It was found that screw holding ability of the tested boards was comparable to those for particleboard and MDF. Moreover, addition of shellac results in increase in that parameter, however the influence of the enzymatic treatment on screw holding occurred ambiguous and strongly dependent on the enzyme type.

Keywords: lignin, enzymatic modification, biocomposites, screw holding capacity

INTRODUCTION

Biocomposites – so called „green composites" – are the materials made of natural fibers (e.g. wood fibers) with biopolymers or bioplastics (Mohanty *et al.* 2000, Maya and Sabu 2008). As natural biodegradable polymer matrices polysaccarides (starch, cellulose, chitin), proteins (collagen/gelation, casein, albumin, fibrogen, silks), polyesters (polyhydroxyalkanoates) and other polymers (lignin, lipids, shellac, natural rubber) can be used (Stevens 2002).

Lignin, aside from cellulose and hemicelluloses, is one of the main constituents of wood. Its content varies from 20 to 30%. When heated, lignin becomes plasticized so that it can be used as a binder for natural fibers (Li *et al.* 1997, Chakar and Ragauskas 2004, Kadla and Kubo 2004, Le Digabel and Ave´rous 2006, Guigo *et al.* 2009). Enzymatic treatments may improve performance of lignin-based biocomposites (Widsten and Kandelbauer 2008).

Up-to-date investigations showed that density (1200 – 1400 kg/m^3) and other properties of those types of composites were comparable to those of glass-fiber reinforced plastics (Mohanty *et al.* 2000). On the other hand, when compared to the hardboard from wet method, lignin-bonded fiberboards exhibit increased hydrophobicity (Boruszewski *et al.* 2010).

Nowadays, the field of biocomposites' applications constantly extends. They are used for furniture and interior applications. What is worth nothing, lignin-bonded biocomposites can be easily 3D-formed in injection moulding or extrusion moulding process.

Due to applications in furniture, screw holding ability seems to be a feature necessary to examine.

MATERIAL AND METHODS

The boards composed of hemp shives (STW 150), Indulin AT (unmodified or enzymatically modified) as the binder and shellac additive were made by injection moulding. The prepared boards characteristics were presented in Table 1. The boards of dimensions 300 x 300 mm^2 were manufactured at the Faculty of Mechanical Engineering, Chemnitz University of Technology. Prior to injection moulding raw materials were dried at 60ºC to 2% moisture content. Mat forming: pre-pressing ~10 N/mm^2, hot pressing ~1 N/mm^2, post-pressing ~5 N/mm^2. Injection temperature 162ºC.

Table 1. Lignin-bonded boards characteristics

Panel type	Lignin	Fiber	Additive	Receipt (Lignin/Fibre/Additive)
A	IAT	STW 150	-	55%/45%/0%
B		STW 150	Shellac dewaxed	40%/45%/15%
C	IAT treated ULB*	STW 150	-	55%/45%/0%
D		STW 150	Shellac dewaxed	40%/45%/15%
E	IAT treated H_2O	STW 150	-	55%/45%/0%
F		STW 150	Shellac dewaxed	40%/45%/15%

* Laccase from *Cerrena unicolor*

The following properties of the boards were analyzed:

- density profile on a laboratory density profile measuring system GreCon DA-X. Measurement resolution 0.02 mm at rate 0,05 mm/s.
- Brinell hardness (according to EN 1534:2000 Wood and parquet flooring. Determination of resistance to indentation (Brinell). Test method)
- screw holding ability (according to EN 13446:2004 Wood-based panels. Determination of withdrawal capacity of fasteners).

Ten specimens were tested in each batch. Statistical significance of differences was tested by Student t-test at 95% confidence interval.

RESULTS AND DISCUSSION

Screw holding ability in the perpendicular setting results were shown in Table 2 and in Fig. 2. The feature determines fasteners' load bearing capacity – e.g. especially in furniture. It depends on the density, elasticity and cohesion of the holding material. Density of the boards ranged from 1312 to 1383 kg/m^3. In general, comparison of the properties can be made when differences between the respective variables do not exceed 10%. The differences in density of the examined boards did not exceed 5.4%. Cross-sectional density variations were shown in Fig. 1. The examined materials, regardless of the thickness, exhibited uniform cross-sectional density profile.

Table 2. Properties of the tested boards

Panel type	Thickness	Density		Brinell hardness		Screw holding ability	
	[mm]	[kg/m^3]	x [%]	[N/mm^2]	x [%]	[N/mm]	x [%]
A	2.52	1383	1	206.6	4	55.78	1
B	3.50	1323	7	228.8	6	77.11	7
C	2.57	1374	1	235.9	8	62.37	12
D	2.65	1359	0.4	258.2	21	72.47	6
E	2.41	1312	11	177.4	11	48.15	6
F	2.55	1343	1	191.1	10	64.02	4

x – variation coefficient

Screw holding ability for all the tested series ranged from 48.15 N/mm to 77.11 N/mm (Table 2, Fig. 2). For the series with shellac as additive, a statistically significant increase in that parameter (16 – 38%) was observed.

The effect of shellac on the hardness was also found. The observed 8-11% increase may be explained by natural high hardness of shellac (Unger *et al.* 2001).

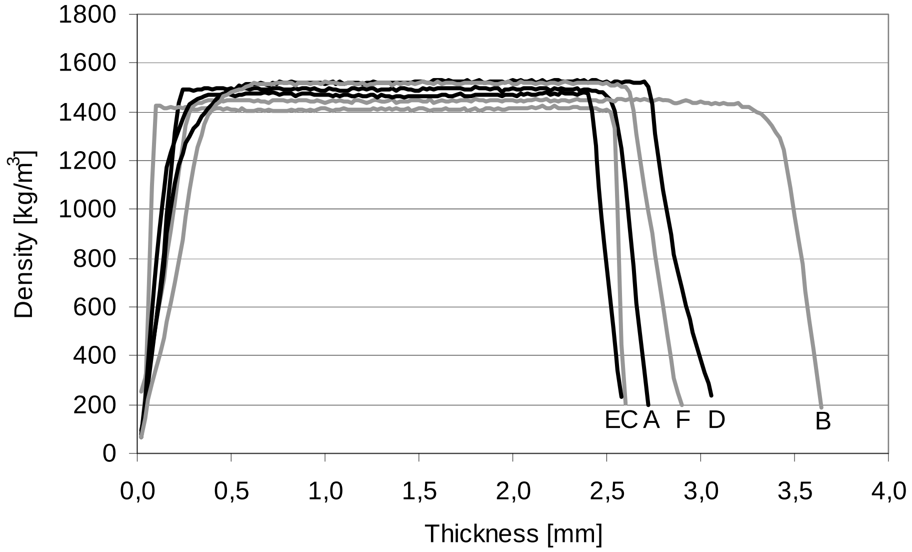

Fig. 1. Cross-sectional density profiles of the tested boards

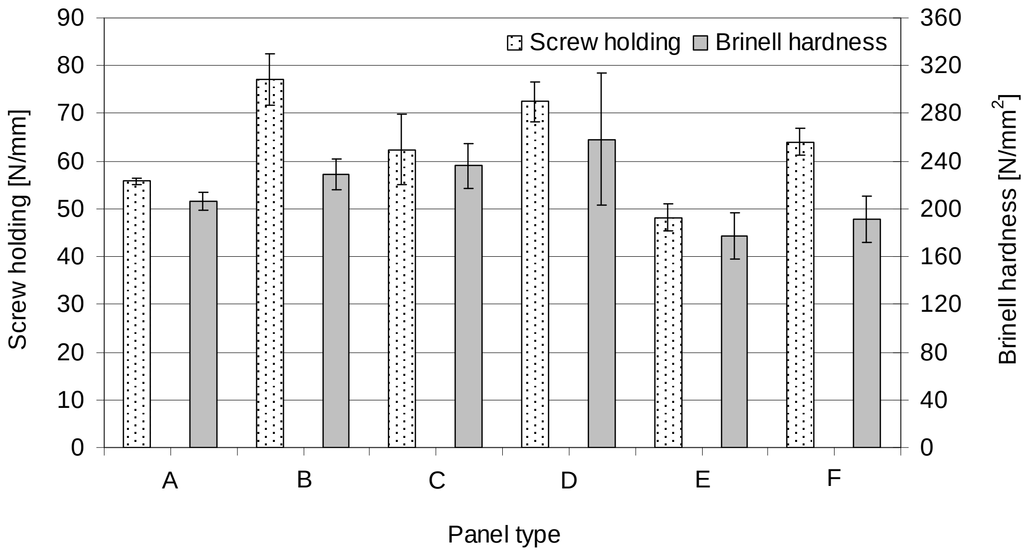

Fig. 2. Screw holding ability and hardness of the boards

Thus, the presented results revealed that enzymatic treatments did not contribute much to the mechanical performance of the studied boards. The effect of type of the enzyme used is ambiguous, since either increase or decrease in screw holding ability was found, respectively for 110118 and 101214 enzyme. Moreover, the differences were statistically significant at 95% confidence interval.

It also must be stressed that the synergistic effect of shellac addition and enzymatic modification of lignin always lowered screw holding ability. Thus, the obtained values of screw holding are comparable to those of particleboards or MDF: 50 – 85 N/mm (Niemz 1993), when the thickness of the material is neglected.

CONCLUSIONS

The studied lignin-bonded fiber composites made by injection moulding exhibited screw holding capacity of 48.15 – 77.11 N/mm2, while the shellac addition contributed to improved screw holding.

The observed differences are statistically significant. However, the influence of the enzymatic treatment on screw holding occurred ambiguous and strongly dependent on the enzyme type.

REFERENCES

1. BORUSZEWSKI P., BORYSIUK P., DOBROWOLSKA E., MAMIŃSKI M., NICEWICZ D., 2010: Interactions with water of novel wood-fiber material with lignins as binder. Annals of Warsaw University of Life Sciences - SGGW. Forestry and Wood Technology, 71/2010, 51-55.
2. CHAKAR F. S., RAGAUSKAS A. J., 2004: Review of current and future softwood kraft lignin process chemistry. Industrial Crops and Products 20, 131–141.
3. GUIGO N., VINCENT L., MIJA A., NAEGELE H., SBIRRAZZUOLI N., 2009: Innovative green nanocomposites based on silicate clays / lignin / natural fibres. Composites Science and Technology 69, 1979–1984.
4. KADLA J. F., KUBO S., 2004: Lignin-based polymer blends: analysis of intermolecular interactions in lignin – synthetic polymer blends. Composites: Part A 35, 395–400.
5. LE DIGABEL F., AVE´ROUS L., 2006: Effects of lignin content on the properties of lignocellulose-based biocomposites. Carbohydrate Polymers 66, 537–545.
6. LI Y., MLYNAR J., SARKANEN S., 1997: The First 85% Kraft Lignin-Based Thermoplastics. Journal of Polymer Science Part B: Polymer Physics 12 (35), 1899–1910.
7. MAYA J. J., SABU T., 2008: Biofibres and biocomposites. Carbohydrate Polymers 71, 343–364.
8. MOHANTY A. K., MISRA M., HINRICHSEN G., 2000: Biofibres, biodegradable polymers and biocomposites: An overview. Macromolecular Materials and Engineering 276/277, 1–24.
9. NIEMZ P., 1993: Physik des Holzes und der Holzwerkstoffe. DRW-Verlag
10. STEVENS E. S., 2002: Green Plastics. Princeton: Princeton University Press.
11. UNGER A., SCHNIEWIND A. P., UNGER W., 2001: Conserwation of Wood Artifacts. Springer Verlag, Berlin.
12. WIDSTEN P., KANDELBAUER A., 2008: Laccase applications in the forest products industry: A review. Enzyme and Microbial Technology 42, 293–307.

ACKNOWLEDGMENT

This work was carried out as a part of the ERA-IB-project: Improvement of strength properties and reduction of emission of volatile organic compounds by enzymatic modification of lignin containing biopolymers and composites (VOC reduction of lignin containing materials) – EIB – 08 – 025.

Streszczenie: *Zdolność utrzymywania wkrętów w biokompozytach spajanych ligniną.* Biokompozyty na bazie ligniny niemodyfikowanej i modyfikowanej enzymatycznie, włókien konopnych i szelaku były wytwarzane metodą wtryskiwania. Dla wytworzonych płyt wyznaczono ich twardość i zdolność utrzymywania wkrętów. Ustalono, że badane płyty charakteryzują się zdolnością utrzymania wkrętów na poziomie zbliżonym do płyt wiórowych i MDF. Wyższe wartości uzyskują kompozyty zawierające w swojej recepturze dodatek szelaku natomiast modyfikacja enzymatyczna ligniny wpływa niejednoznacznie na wartość zdolności utrzymywania wkrętów. Jej efekt jest uzależniony od efektywności zastosowanego enzymu.

Corresponding authors:

Piotr Boruszewski, Piotr Borysiuk, Mariusz Mamiński,
Faculty of Wood Technology,
Warsaw University of Life Sciences – SGGW,
02 – 776 Warsaw,
159 Nowoursynowska st.,
Poland,
e-mail: piotr_boruszewski@sggw.pl
e-mail: piotr_borysiuk@sggw.pl
e-mail: mariusz_maminski@sggw.pl