Wood-mineral wool hybrid particleboards

M. Ł. Mamiński, M. E. Król, W. Jaskólowski, P. Borysiuk

Wood-mineral wool hybrid particleboards

M.Ł. Mamiński[a] (✉), M.E. Król[a], W. Jaskółowski[b], P. Borysiuk[a]

[a]Warsaw University of Life Sciences – SGGW, Faculty of Wood Technology
159 Noakowskiego St., 02-776 Warsaw, Poland
[b]The Main School of Fire Service
52/54 Słowackiego St., 01-629 Warsaw, Poland

**corresponding author: mariusz_maminski@sggw.pl*

Abstract. The objective of this work was to compound mineral wool with wood particles in the production of particleboards of reduced flammability. Three series of boards with various contents of mineral wool (10, 20, 30 wt%) were successfully manufactured using urea-formaldehyde resin as binder. Thickness swelling, mechanical and thermal properties as well as ignitability of the boards were assessed. It occurred that reduced ignitability is accompanied by a decrease in mechanical performance.

1. Introduction

There are several types of insulating materials commonly used in engineering. The three main groups of the boards used in house construction are: (1) natural wood-based materials – like low density fiberboard, insulation board from kenaff, hemp or wood fiber; (2) synthetic foams (polystyrene or polyurethane) and (3) boards based on natural inorganic materials (glass wool or mineral wool). On the contrary to wood-based materials or synthetic foams, the main advantage of mineral wool, apart from excellent insulation properties, is its inflammability (Karamanos et al. 2008).

There are some reports on compounding wood material with mineral components – like vermiculite (Kozłowski et al. 1999), cement (Okino et al. 2005; Qi et al. 2006) or potassium aluminosilicate (Giancaspro et al. 2008).

In some applications low flammability of the materials accompanied by retention of mechanical properties is required. In such cases, the use of particleboards with reduced flammability seems to be reasonable. Thus, an attempt of hybrid wood – mineral wool boards manufacturing by compounding of mineral wool with wood particles was undertaken. In this paper some thermal, sorptive and mechanical properties of the manufactured boards were described.

2. Materials and methods

Three series of one-layer particleboards (330 x 330 x 12 mm^3, density 600 kg/m^3) with 10, 20 or 30 wt% on dry wood basis of mineral wool were prepared. The boards were made of industrial grade chips (6.0% moisture content) and mineral wool (2.2% moisture content). A commercial urea-formaldehyde (UF) resin was used as adhesive. Glue formulation: UF 50 parts by weight, 10% ammonium chloride 1.2 parts by weight, water 12 parts by weight. Glue rate 10 wt%. Same boards without mineral wool were used as controls.

Compounding of the materials involved three steps: (1) shredding of the wool into small pieces (*ca.* 5-10 mm), (2) mixing of the wool with wood particles, (3) blending of the mixture with glue. Then, a mat was formed and pressed under the following conditions: platens temperature 180ºC, maximum unit pressure 2.5 MPa, time 291 s. Prior to testing, the boards were conditioned at 20±2 ºC and 65±5% RH for 7 days.

The ignitability was tested according to EN ISO 11925-2, modulus of rupture (MOR) according to EN 310 and internal bond (IB) according to EN 319. Thickness swelling was measured according to EN 317. Thermal conductivity and thermal capacity were analyzed on an ISOMET 2140 heat transfer analyzer (Applied Precision) instrument. Density profiles were measured on an X-ray density analyzer DA-X (GreCon).

3. Results and discussion

During ignitability tests neither 15 nor 30 s flame application caused self-sustainable fire. At last, 120 s flame treatment occurred to be necessary for ignition and path smouldering onto samples. As indicated in Table 1, there is no difference between the length of the smouldering path of the control and the 10% series. Only 20% addition of wool affected and shortened smouldering path by 19%, while 30% addition of wool reduced that parameter by 30% when compared to the controls. The reduction in ignitability is proportional to the content of the mineral component.

The values of thermal conductivity and thermal capacity measured for the studied boards are shown in Table 1. The data indicate that as small as 10% content of wool did not alter significantly those parameters, however, 20% and 30% additions resulted in a stepwise decrease in thermal conductivity by 7%, whilst changes in thermal capacity were monotonic and achieved 11% and 19%, respectively, when compared to the controls. Having in mind that thermal conductivity for uncompressed mineral wool is 0.033 W/mK and that wool within the board is somehow compressed, the effect of the resultant efficacy of insulating is reasonable.

Unlike thermal properties, the highest modulus of rupture (MOR) and internal bonding (IB) values were observed for the controls. Thus, it is obvious that addition of wool resulted in a decrease in mechanical properties - MOR by 27% - 65% and IB by 32% and 71% for 20% and 30% of wool, respectively. However, 10% addition of wool did not affect IB. The deterioration of mechanical performance is ascribed to the low cohesion of the wool domains within the board. It is worth noting that the density profiles of the hybrid boards and that of the control shown in Fig. 1 are very much alike which proves satisfying dispersion of wool among wood particles, and that required density of a board can be achieved. Therefore, the proposed method of compounding was found efficient.

Table. 1

Fig. 1

Surprisingly, the obtained values of thickness swelling exhibited by 10%-series were slightly reduced which can be explained by compensation of dimensional changes within the wool domains, so that overall swelling of the board was avoided. For the higher content of wool, the effect was overwhelmed by an intense overall swelling.

4. Conclusion

In summary it can be concluded that hybrid particleboards with 20% mineral wool exhibit improved insulating properties and reduced ignitability, which – unfortunately – are accompanied by a deterioration of the mechanical properties. The described approach based on typical particleboard preparation procedure allows for compounding of mineral wool with wood particles. However, for the improved performance of the resultant hybrid particleboards, degree of wool shredding and wool pieces dimensions as well as glue load and pressing parameters should be considered for future work.

References

EN 310 (1994) Wood-based panels - Determination of modulus of elasticity in bending and bending strength

EN 317 (1999) Particleboards and fiberboards - Determination of swelling in thickness after immersion in water

EN 319 (1999) Particleboards and fiberboards - Determination of tensile strength perpendicular to the plane of the board

EN ISO 11925-2 (2002) Reaction to fire tests -- Ignitability of building products subjected to direct impingement of flame -- Part 2: Single-flame source test

Giancaspro J, Papakonstantinou C, Balaguru P (2008) Fire resistance of inorganic sawdust biocomposite. Compos Sci Technol 68: 1895–1902

Karamanos A, Hadiarakou S, Papadopoulos AM (2008) The impact of temperature and moisture on the thermal performance of stone wool. Energ Buildings 40: 1402–1411

Kozlowski R, Mieleniak B, Helwig M, Przepiera A (1999) Flame resistant lignocellulosic-mineral composite particleboards. Polym Degrad Stabil 64: 523–528,

Okino EYA, de Souza RM, Santana MAE, da S. Alves MV, de Sousa ME, Teixeira DE (2005) Physico-mechanical properties and decay resistance of *Cupressus spp.* cement-bonded particleboards. Cement Concrete Comp 27: 333–338

Qi H, Cooper PA, Wan H (2006) Effect of carbon dioxide injection on production of wood cement composites from waste medium density fiberboard (MDF). Waste Manage 26: 509–515

Fig. 1 Density profiles of the studied boards

Abb. 1 Dichteprofile der untersuchten Platten

Table. 1 Selected properties of the hybrid boards studied

Tabelle 1 Ausgewählte Eigenschaften der untersuchten Hybridplatten

Wool content	**Density**	**Smouldering path length**	**Thermal conductivity**	**Thermal capacity**	**MOR**	**IB**	**Thickness swelling after 24 h soaking**
[wt%]	**[kg/m^3]**	**[cm]**	**λ [W/mK]**	**Cp [J/m^{3}K]**	**[N/mm^2]**	**[N/mm^2]**	**[%]**
0	597 (18)	13.5	0.144	0.765	10.9 (0.9)	0.31 (0.03)	36.1 (5.0)
10	595 (31)	13.5	0.143	0.755	7.9 (1.4)	0.31 (0.04)	31.6 (2.3)
20	596 (32)	11.0	0.134	0.680	6.4 (0.8)	0.21 (0.03)	39.6 (6.0)
30	570 (42)	9.5	0.133	0.619	3.8 (0.7)	0.09 (0.01)	49.1 (9.1)

*Values in parentheses are standard deviations. **λ for mineral wool is 0.033 W/mK.

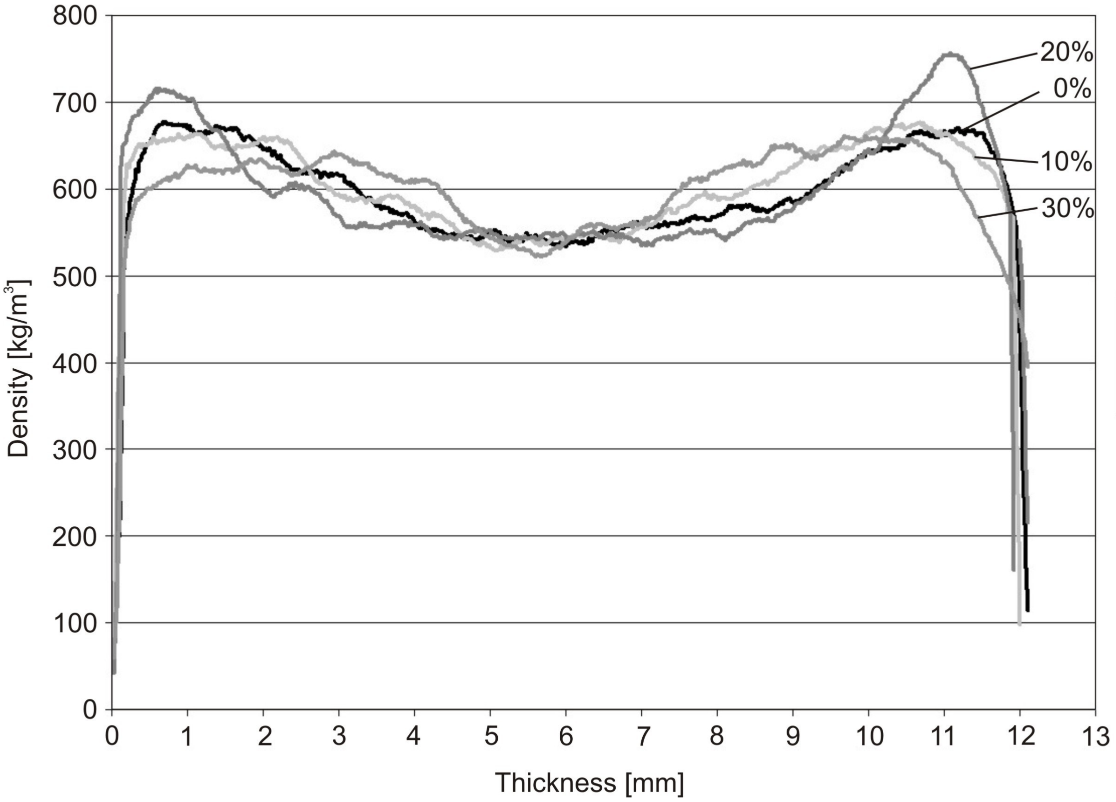
800
700
600
500
400
300
200
100
0
Density [kg/m³]
0
1
2
3
4
5
6
7
8
9
10
11
12
13
Thickness [mm]
20%
0%
10%
30%

Fig. 1