ELECTRONIC JOURNAL OF POLISH AGRICULTURAL UNIVERSITIES

2010
Volume 13
Issue 3
Topic
WOOD TECHNOLOGY

MIRSKI R. 2010. THE EFFECT OF VARIABLE ENVIRONMENTAL CONDITIONS ON DIMENSIONAL CHANGES IN THIN WOOD-BASED MATERIALS PART II. DESORPTION CHANGES, EJPAU, 13(3), #13.
Available Online http://www.ejpau.media.pl

THE EFFECT OF VARIABLE ENVIRONMENTAL CONDITIONS ON DIMENSIONAL CHANGES IN THIN WOOD-BASED MATERIALS PART II. DESORPTION CHANGES

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ABSTRACT

The study comprised an analysis of dimensional changes in thin wood-based boards caused by cyclical changes in relative humidity at constant ambient temperature. Analyses were conducted on MDF, HDF, PB and OSB. As a result of these investigations it was found that final relative dimensional changes are significantly dependent on changes in dimensions occurring at individual stages of conditioning, with the first adsorption changes being most important. The lowest relative change in length determined in relation to the initial length was found for MDF board, while that in thickness – for HDF board.

Key words: MDF, HDF, PB, OSB, dimensional stability

INTRODUCTION

Changing environmental conditions, primarily due to changes in humidity, cause permanent work of elements made of wood, observable directly as changes in their linear dimensions. Most users of solid wood materials have observed the formation of gaps in wooden floors, warping of doors or loss of air-tightness in windows. It results from basic knowledge on the subject that at gradual moistening and next drying of wood different wood moisture contents are obtained at identical relative humidity, i.e. the so–called sorption curves [1]**.** A similar behaviour may also be expected in case of wood-based materials. However, the shape/dimensions of a given board depending on the number of changes and intensity of the moistening or drying processes, may vary for the same relative humidity. This may result not only from different equilibrium moisture contents, but it may also be an effect of changes occurring in the glue line. Dimensional stability of wood-based materials caused by changes in relative humidity makes this a topical issue and the aim of numerous studies is to provide insight not only into the problem itself, but also determine the volume of these changes [3, 4].

This study is a continuation of earlier investigations, in which dimensional changes were determined in thin wood-based materials subjected to cyclical changes in relative humidity at constant ambient temperature [2]. In turn, the aim of this study was to identify the volume of these changes in case when these materials are subjected to cyclical changes in humidity, in which stages of high humidity predominate.

MATERIAL AND METHODS

Analyses were conducted on MDF, HDF, PB as well as OSB/3 and OSB/4 with thickness ranging from 6 to 8 mm. A complete characteristic of tested boards are presented in Table 1 [2].

Table 1. Properties of tested boards

Property	Testing method	Unit	Kind of boards				
			MDF	HDF	PB	OSB/3	OSB/4
	PN-EN	mm	7	6	7	8	8
ρ	323	[kg/m^3]	740	890	850	720	730
MOR II	310	[N/mm^2]	36,6	53,6	25,9	40	42
MOR⊥	310	[N/mm^2]	–	–	–	23	25
MOE II	310	[N/mm^2]	3760	4940	4900	5790	6060
MOE ⊥	310	[N/mm^2]	–	–	–	2550	3220
IB	319	[N/mm^2]	0,74	1,42	1,28	0,48	0,83
V100	1087-1	[N/mm^2]	–	–	0,24	0,46	0,37
V313	321	[N/mm^2]	–	0,35	–	-	-

Table 2. The course of the conditioning process

Stage	0		I		II		III		IV		-
Degree	0	1*	2*	3*	4	5	6	7	8	9	10
Relative humidity [%]	65	85	65	30	65	85	65	30	65	85	65

*– degrees assumed in standard PN-EN 318

In order to determine the effect of humidity at a temperature of 20ºC boards were exposed to a cyclical action of air with humidity levels of 85%, 65% and 30%. Adopted levels of relative humidity and the used testing machine complied with respective standard EN 318. This standard assumes only three conditioning degrees (1–3), whereas in this study this number was increased and the concept of a stage was introduced, referring to a period after which it was decided to determine dimensional changes of boards following formula 1.1. A complete conditioning cycle is presented in Table 2.

$$\delta l_{65,x} = \frac{l_{xn} - l_{65(n-1)}}{l_{65(n-1)}} \times 1000 \quad \text{[mm/m]}$$
$$\delta t_{65,x} = \frac{t_{xn} - t_{65(n-1)}}{t_{65(n-1)}} \times 100 \quad [\%] \qquad 1.1$$

where:

x – the level of relative humidity, after which relative change in length or thickness is determined,
n – degree n = 1, 3, 5, 7, 9,
$\delta l_{65,x}$ – relative change in length at a change in relative humidity from 65% to x, mm/m,
$\delta t_{65,x}$ – relative change in thickness at a change in relative humidity from 65% to x, %.

The adopted pattern of changes in relative humidity for stages 1, 2 and 3 corresponds to desorption changes consistent with standard EN-318, thus it was decided to denote the assumed conditioning schedule as a desorption schedule.

Analysis of linear dimensions defined after the zero and the tenth conditioning stages ($65_{10} \rightarrow 65_0$) should facilitate the determination of permanent dimensional changes, which occurred in the tested material as a result of the entire conditioning period.

RESULTS AND DISCUSSION

The effect of relative humidity on relative changes in linear dimensions of the tested thin wood-based boards are presented in Tables 3–6. It results from the presented data that after the zero stage of the analysis the biggest relative change in length was recorded for the shorter axis of OSB. Moreover, in case of OSB/3 the obtained value of 1.61 mm/m was almost two times bigger than the volume of this change for the longer axis (0.81 mm/m). It needs to be stressed that the volume of observed changes occurring in the tested boards may by affected by both their density, the degree of fineness and the structure of the board itself. Thus, when dividing the tested materials into two groups, i.e. those made from fibres and those made from chips, in case of fibreboards a bigger increment in length was recorded for HDF, by nature characterized by a bigger density than MDF. In turn, an opposite dependence was recorded for other group of boards. It was observed that particleboard, despite a much bigger density (on average by 125 kg/m^3) [2], showed a lower relative change in length. Moreover, it needs to be stressed that after conditioning OSB was characterized by an approx. 2% higher moisture content in comparison to particleboards. Such fluctuations in changes may result from the required higher resination rate, necessary for binding chips with smaller dimensions.

Table 3. Changes in length of MDF and HDF occurring under the influence of changes in relative humidity

Stage	Change in humidity	Relative change in humidity	Relative change in length	Standard deviation	Relative change in length	Standard deviation
			MDF		HDF	
	[%]	H [%]	δ_l[mm/m]	σ[mm/m]	δ_l[mm/m]	σ[mm/m]
0	65→85	*12.3*	0.67	*0.09*	*12.9*	*0.72*
I	65→30	*4.9*	-1.19	*0.09*	*4.9*	*-1.28*
II	65→85	*12.2*	0.61	*0.04*	*12.2*	*0.59*
III	65→30	*5.7*	-0.77	*0.11*	*5.7*	*-0.72*
IV	65→85	*12.8*	0.45	*0.07*	*12.8*	*0.53*

Table 4. Changes in length of particleboards occurring under the influence of changes in relative humidity

PB				
Stage	Change in humidity	Relative change in humidity	Relative change in length	Standard deviation
	[%]	H [%]	δ_l[mm/m]	σ[mm/m]
0	65→85	*12.1*	0.70	*0.08*
I	65→30	*4.7*	-1.30	*0.20*
II	65→85	*12.8*	0.62	*0.05*
III	65→30	*5.5*	-0.80	*0.03*
IV	65→85	*12.7*	0.55	*0.04*

Table 5. Changes in length of OSB/3 and OSB/4 occurring under the influence of changes in relative humidity determined along the longer axis

Stage	Change in humidity	Relative change in humidity	Relative change in length	Standard deviation	Relative change in length	Standard deviation
			OSB/3		OSB/4	
	[%]	H [%]	δ_l[mm/m]	σ[mm/m]	δ_l[mm/m]	σ[mm/m]
0	65→85	*14.2*	0.81	*0.11*	0.77	*0.10*
I	65→30	*6.0*	-0.60	*0.04*	-0.52	*0.06*
II	65→85	*13.3*	0.86	*0.26*	0.65	*0.38*
III	65→30	*6.2*	-0.57	*0.06*	-0.52	*0.10*
IV	65→85	*12.9*	0.91	*0.24*	0.79	*0.14*

Table 6. Changes in length of OSB/3 and OSB/4 occurring under the influence of changes in relative humidity determined along the shorter axis

Stage	Change in humidity	Relative change in humidity	Relative change in length	Standard deviation	Relative change in length	Standard deviation
			OSB/3		OSB/4	
	[%]	H [%]	δ_l[mm/m]	σ[mm/m]	δ_l[mm/m]	σ[mm/m]
0	65→85	*14.2*	1.61	*0.20*	1.17	*0.11*
I	65→30	*6.0*	-0.83	*0.18*	-0.69	*0.05*
II	65→85	*13.3*	1.29	*0.10*	1.01	*0.21*
III	65→30	*6.2*	-0.93	*0.06*	-0.77	*0.12*
IV	65→85	*12.9*	1.22	*0.16*	0.83	*0.15*

Under the influence of further conditioning (stages II, IV) in case of MDF, HDF and PB, as well as the shorter axis of OSB, a gradual decrease was recorded for the obtained values of relative changes in length. For the above mentioned materials these values after stage IV of conditioning were by approx. 30% lower than those recorded after stage 0. In turn, in case of the longer axis of OSB, further stages of conditioning did not result in significant differences in relative changes in length. A slight increment was observed only in the relative change in length of OSB/3, although it was at a relatively high standard deviation. Such a behaviour of boards was probably affected by shrinkage caused by indirect conditioning of boards at relative humidity of 30% (stages I and III). Samples of MDF, HDF and PB shrank very intensively, particularly after stage I, while shrinkage was smallest in OSB samples collected for the longer axis.

Results of analyses on relative changes in thickness for stages, in which the adsorption process took place, are presented in Fig. 1. It results from investigations conducted in this respect that the biggest increment in thickness was found for OSB, while the smallest for HDF. In case of HDF swelling increased by only 2%, in relation to the over 3-fold bigger value in case of OSB/3.

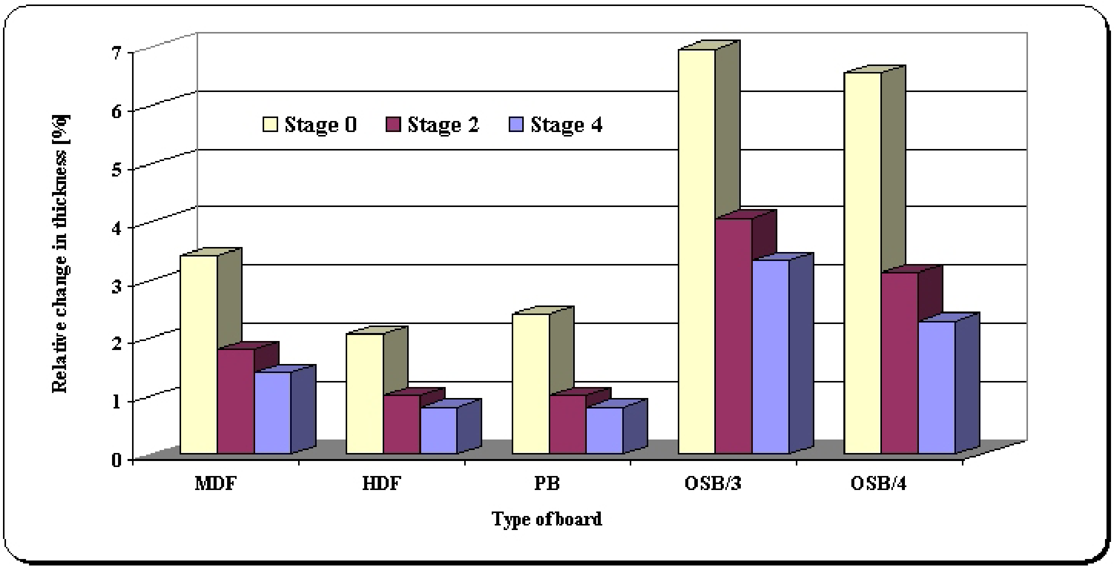

Fig. Relative changes in thickness determined for adsorption stages

In successive stages a considerable reduction was observed in the values of relative changes in thickness, while the biggest changes in this respect were found for particleboard and OSB/4. Differences in the volume of relative changes in thickness between the first and the second stage ranged between 40% and 60%, while between the second and the third stage they amounted to approx. 20%–25%. It needs to be stressed that for each stage a different base thickness was assumed, since it was the thickness recorded for samples of tested boards after their conditioning at relative humidity of 65%, beginning each stage. The zero stage, in which moistening of samples took place, probably caused the formation of very significant non-recoverable thickness swelling (NTS). It results from a study by Wu and Piao [5] that in case of OSB exceeding board moisture content of 10–12% results in the formation of considerable deformations in thickness, being NTS in character. The generation of these deformations is only partly neutralized at the successive conditioning processes, in which samples were exposed to the action of air at a 30% humidity. It may be seen in data given in Fig. 2 for successive desorption processes that the volume of relative changes in thickness increases. Moreover, it results from the presented data that for the first stage of conditioning, except for particleboard, the other boards are characterized by similar shrinkage, amounting to approx. 1.35%. However, already after the next stage (stage III) a much bigger shrinkage may be observed for MDF and OSB/3. In turn, relative changes in thickness, both adsorption and desorption changes, were observed for PB in the successive cycles are generally smaller than in case of the other boards. Slight fluctuations in dimensional changes in particleboard depending on changes in relative humidity were already found in the earlier study [2]. It was explained by considerable density, a high degree of resination and/or increased addition of hydrophobic agents, resulting from the intended use of boards for floor panelling, which forces board producers to significantly improve hydrophobicity of such material.

Total changes in length and thickness, which occurred in the tested material in the course of 11 cycles of conditioning (10→0), are presented in Figs. 3 and 4. The smallest increment in length was found for MDF, while that in thickness for HDF. In turn, the biggest changes, both in length and thickness, were recorded for OSB/3. Relative change in length for the shorter axis of OSB/3 was almost 1 mm/m and it was almost 3 times bigger than that found for MDF. In turn, increment in thickness for this board was over 6 times bigger than that for the board with the lowest increment, i.e. HDF. Such considerable differences could have been caused by slight, although observable, higher moisture contents of OSB during the entire period of their conditioning.

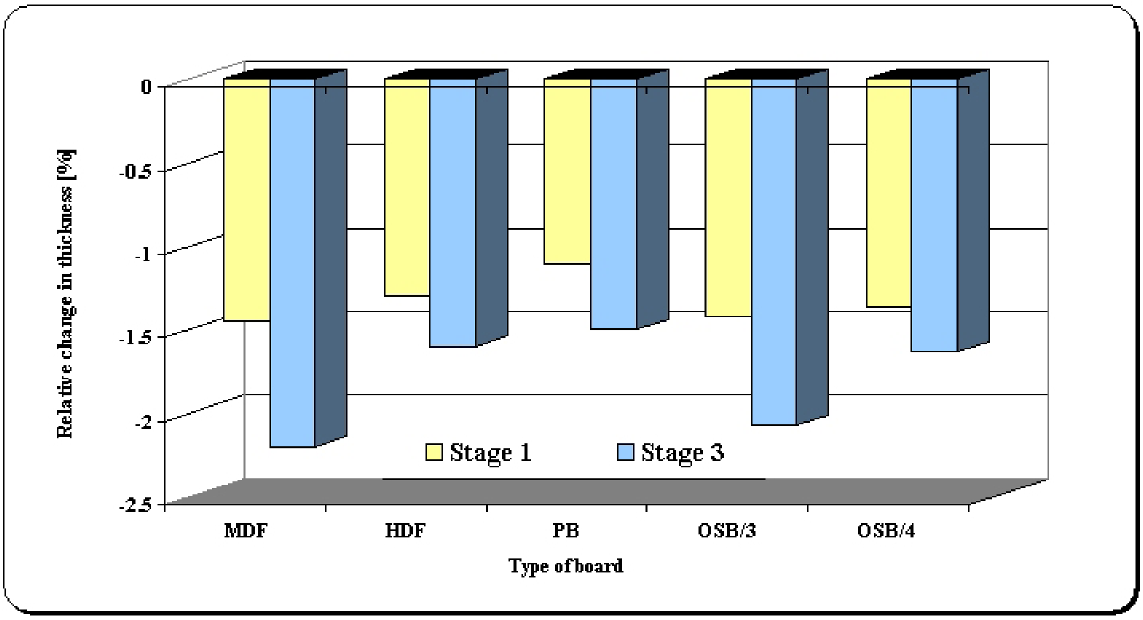

Fig. 2. Relative changes in thickness determined for desorption stages

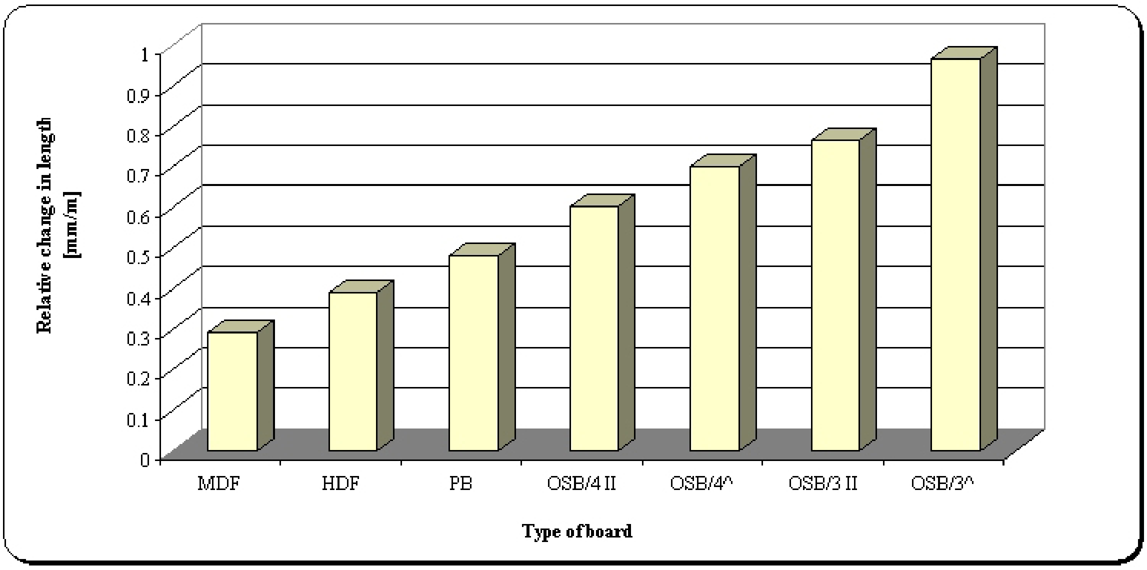

Fig. 3. Relative changes in length of boards determined between conditioning stages 10→0

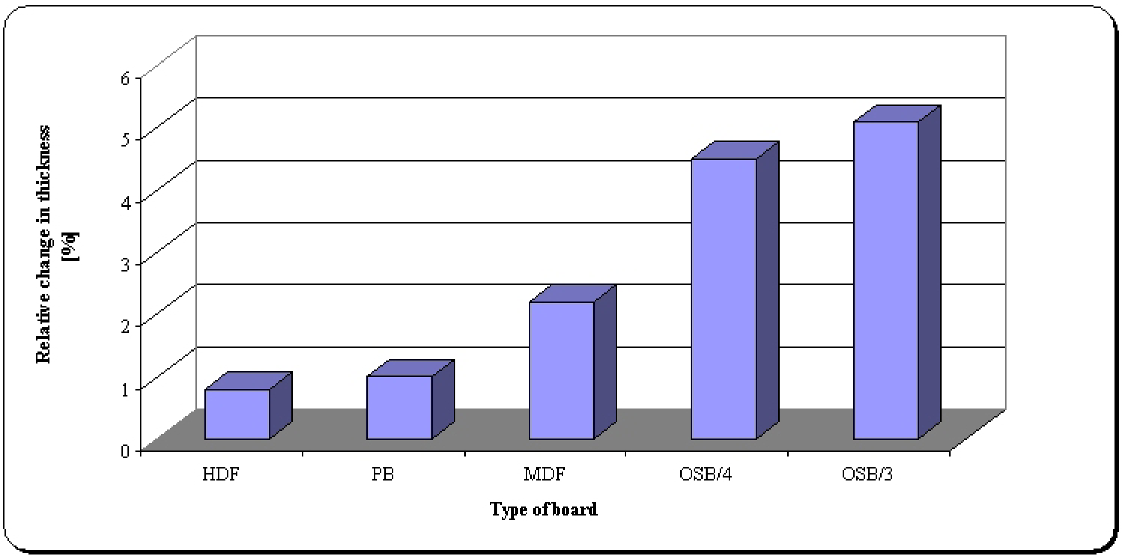

Fig. 4. Relative changes in thickness of boards determined between conditioning stages 10→0

When comparing the results for the total increments in length and thickness with the results reported in the earlier study [2] concerning adsorption changes it may be observed that boards to be used as core of both floor and wall panels and produced from fibreboards were the least susceptible to the direction of forced dimensional changes. Moreover, it results from conducted analyses that subjecting tested materials first to the wetting process results in the formation of much bigger dimensional deformations than in the course of processing with the use of dry air. Relative changes in length determined after the completion of the conditioning period, except for HDF, were by over 20%, while in OSB for the shorter axis they were by over 60% higher than those determined in the earlier study.

CONCLUDING REMARKS

It was found as a result of conducted investigations that final relative dimensional changes in boards were significantly dependent on dimensional changes occurring at individual stages of conditioning, with the first adsorption change being apparently the most significant. Considerable loosening of structure in the tested materials, caused by relative humidity of 85% at the zero stage of analyses, results in the formation of deformations, which are not recoverable even as a result of conditioning at a relatively low relative humidity, amounting to 30%. It seems that for this reason the evaluation of only the relative changes in linear dimensions determined for cyclical changes in relative humidity is insufficient. It results from the conducted analyses that for individual conditioning stages relatively low relative changes in length and thickness are found for particleboard. However, the smallest relative change in length defined in relation to initial length was found for MDF, while that in thickness for HDF.

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Accepted for print: 13.09.2010