WOOD RESEARCH
58 (1): 2013
91-100

THE EFFECT OF AMBIENT CONDITIONS ON DIMENSIONAL STABILITY OF OSB/4

Radosław Mirski, Dorota Dziurka
Poznań University of Life Sciences, Department of Wood-Based Materials
Poznań, Poland

(Received October 2010)

ABSTRACT

The study investigated dimensional changes of OSB/4 caused by cyclical changes in relative humidity at a constant ambient temperature. As a result of conducted analyses it was found that relative changes in length of OSB/4 to a much higher degree depend on the course of changes in relative humidity than on their thickness. Cyclically changing relative humidity causes an increase in board length in relation to its original length, irrespective of the direction of their changes. In turn, a relative change in thickness of OSB/4 calculated for individual stages is inversely proportional to board thickness.

KEYWORDS: OSB, humid conditions, dimensional stability.

INTRODUCTION

Wood-based materials produced in the process of pressing at elevated temperature, even despite the application of water-resistant adhesives and additives improving their hydrophobicity, immediately after being removed from the press are subjected to the process of adaptation to environmental conditions. This process is connected first of all with changes in their moisture content and curing. Dimensional changes taking place in that time result primarily from humidity changes. Although this process is stopped after an equilibrium is reached between wood-based materials and the environment, the observed linear dimensions for a given board are not final and during the life of the product undergo further changes with changing climatic conditions of the environment. Dimensional changes in different types of wood-based materials have been investigated for many years now. Research studies conducted on the subject pertain first of all to changes in length caused by changes in relative humidity at room or elevated temperature (Constant et al. 2003, Pugel et al. 1990, Sekino and Shibusawa 2002).

In turn, Suzuki and Miyamoto (1998) investigated changes in length in single-layer particleboards subjected to the action of air at a temperature of 40°C and 90 % RH as well as soaking in water. As a result of conducted analyses those authors stated that observed changes in length of boards are proportional to their density. However, not all researchers share the opinion that changes in length of particleboards are proportional to their density. Both Suchsland

(1972) and Kelly (1977) stated in their studies that density does not have a significant effect on changes in their length. A linear dependence of changes in length on board density was also reported in his study by Ayrilmis (2007). However, in this case analyses were conducted on felted fibreboards, which were conditioned according to the assumptions of standard EN 318, i.e. in air at a temperature of 20°C and relative humidity of 30, 65 and 85 %.

However, it needs to be stressed that both tested single-layer particleboards and fibreboards are characterized by a relatively homogenous structure in terms of the size of their "particles" and their arrangement at the cross-section of the board. Thus an interesting aspect is to determine how a three-layer OSB, with oriented chips in individual layers, in which the difference in density between individual layers may be as high as 300 kg.m^{-3}, would react to changes in humidity and their frequency. It may be assumed that the observed linear changes occurring in moistened material are significantly affected by the action of individual layers considerably differing in density, as well as a specific arrangement of chips in the board. Thus the aim of this study was to investigate dimensional changes of OSB/4 caused by cyclical changes in relative humidity at a constant ambient temperature.

MATERIAL AND METHODS

Analyses were conducted on industrial OSB/4 with board thickness of 15 and 22 mm, resinated in the centre layer with PMDI, while in the surface layers with melamine-urea-phenol-formaldehyde resin (MUPF). According to EN-300 2006 OSB/4 mean heavy duty load-bearing boards for use in humid conditions.

Prior to testing the following properties were determined according to respective standards:

- swelling in thickness after 24 h according to EN 317 1993,
- internal bond after the boiling test according to EN 1087-1 2001,
- internal bond according to EN 319 2012,
- modulus of rupture and modulus of elasticity according to EN 310 2002.

Properties of OSB/4 determined on the basis of respective standards are presented in Tab. 1. It results from presented data that properties of tested OSB/4 generally considerably exceed values required by standard EN 300.

Tab. 1: Properties of tested OSB/4.

Property	Testing method	Unit	Numerical value			
			Board thickness (mm)			
			15		22	
			Tested*	Recommended by EN 300	Tested	Recommended by EN 300
ρ	EN 323	kg.m^{-3}	620	-	670	-
G_t	EN 317	%	10	12	5	12
f_m II	EN 310	N.mm^{-2}	27	28	34	26
$f_m \perp$	EN 310	N.mm^{-2}	21	15	21	14
E_m II	EN 310	N.mm^{-2}	5440	4800	6390	4800
$E_m \perp$	EN 310	N.mm^{-2}	3140	1900	3380	1900
$f_{t\perp}$	EN 319	N.mm^{-2}	0.59	0.45	0.77	0.40
V100	EN 1087-1	N.mm^{-2}	0.15	0.15	0.14	0.13

** – mean values*

Dimensional changes in OSB/4 caused by changes in relative humidity were determined based on the assumptions of standard PN-EN 318 2008. This standard takes into consideration only three degrees of sample conditioning in air with varying humidity and constant temperature, while in this study it was decided to increase their number to 11 and introduce the term of "stage". A complete course of the conditioning process is presented in Tab. 2.

Moreover, it was decided to analyze samples of batch 1 as subjected to desorption, while those of batch 2 as subjected to adsorption. After each of the conditioning stage lenght, thickness and weight of samples were measured. Samples for testing were gained from two different lot of panels. A total of 9 samples both for major and minor axis were cut from each board. Results of analyses of individual properties were thus a mean of 18 measurements. Results of these determinations were subjected to statistical analysis.

Relative dimensional changes were determined according to the following formulas:

$$\delta l_{65,x} = \frac{l_{x(n+1)} - l_{65n}}{l_{65n}} \times 1000 \quad (\mathrm{mm.m^{-1}}) \qquad (1)$$

$$\delta t_{65,x} = \frac{t_{x(n+1)} - t_{65n}}{t_{65n}} \times 100 \quad (\%) \qquad (2)$$

where: x – value of relative humidity after which relative changes in length or thickness were 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,
$\delta t_{65,x}$ – relative change in thickness at a change in relative humidity from 65 % to x.

Tab. 2: The course of the conditioning process.

Stage	Degree	Set no. 1	Set no. 2
I	1	20°C, 65 % RH	20°C, 65 % RH
	2*	20°C, 30 % RH	20°C, 85 % RH
II	3*	20°C, 65 % RH	20°C, 65 % RH
	4*	20°C, 85 % RH	20°C, 30 % RH
III	5	20°C, 65 % RH	20°C, 65 % RH
	6	20°C, 30 % RH	20°C, 85 % RH
IV	7	20°C, 65 % RH	20°C, 65 % RH
	8	20°C, 85 % RH	20°C, 30 % RH
V	9	20°C, 65 % RH	20°C, 65 % RH
	10	20°C, 30 % RH	20°C, 85 % RH
-	11	20°C, 65 % RH	20°C, 65 % RH

* - *degrees assumed in standard EN 318.*

After finished conditioning process all samples were oven-dried to dry matter in order to determinate moisture content.

RESULTS AND DISCUSSION

Changes in length of OSB/4 occurring under the influence of changes in relative humidity are presented in Tabs. 3 and 4. As it results from these data, much bigger longitudinal strain was observed in boards if measurements were taken along the shorter axis. Values recorded in that case were from 10 to 55 % higher than those found along the longer axis, with the changes being much bigger for thicker boards.

Tab. 3: Changes in length of OSB/4 with a thickness of 15 mm occurring under the influence of changes in relative humidity.

Stage	Change in humidity	Longer axis		Shorter axis	
		Relative change in length	Standard deviation	Relative change in length	Standard deviation
	(%)	δ_l (mm.m^{-1})	σ (mm.m^{-1})	δ_l (mm.m^{-1})	σ (mm.m^{-1})
Set no. 1					
I	65→30	-0.43	0.06	-0.55	0.10
II	65→85	0.74	0.12	0.93	0.09
III	65→30	-0.69	0.06	-0.82	0.06
IV	65→85	0.73	0.13	0.82	0.16
V	65→30	-0.68	0.12	-0.85	0.10
Set no. 2					
I	65→85	0.83	0.08	1.01	0.10
II	65→30	-0.60	0.06	-0.75	0.14
III	65→85	0.74	0.10	0.86	0.06
IV	65→30	-0.55	0.14	-0.55	0.20
V	65→85	0.74	0.16	0.86	0.10

Tab. 4: Changes in length of OSB/4 with a thickness of 22 mm occurring under the influence of changes of relative humidity.

Stage	Change in humidity	Longer axis		Shorter axis	
		Relative change in length	Standard deviation	Relative change in length	Standard deviation
	(%)	δ_l (mm.m^{-1})	σ (mm.m^{-1})	δ_l (mm.m^{-1})	σ (mm.m^{-1})
Set no. 1					
I	65→30	-0.49	0.05	-0.68	0.04
II	65→85	0.61	0.08	0.95	0.07
III	65→30	-0. 56	0.33	-0.76	0.03
IV	65→85	0.75	0.19	1.18	0.06
V	65→30	-0. 67	0.25	-0.84	0.02
Set no. 2					
I	65→85	0.67	0.05	1.02	0.09
II	65→30	-0.63	0.07	-0.86	0.09
III	65→85	0.57	0.19	0.69	0.07
IV	65→30	-0.60	0.30	-0.77	0.05
V	65→85	0.49	0.17	0.63	0.08

If for 15 mm thick boards relative changes in length recorded at the same stages were bigger by max. approximately 30 %, then in 22 mm thick boards they reached even 55 %. No such considerable change was observed in an earlier study concerning OSB/3 (Mirski et al. 2007), while a similar dependence was reported in their study by Wu and Suchsland (1996), who investigated changes in length of commercial OSB subjected to gradual moistening in air with humidity ranging from 35 to 95 %. In turn, assuming after Suzuki and Miyamoto (1998) the opinion that changes in length are proportional on density it needs to be expected that in OSB face layers will determine the volume of these changes depending on board thickness. At a comparable density of the centre layers (570±10 $kg.m^{-3}$) (Fig. 1), density of outer layers of the board with a thickness of 15 mm was 685 $kg.m^{-3}$, while for boards with a thickness of 22 mm it was 790 $kg.m^{-3}$. It seems that the difference in density amounting to as much as 100 $kg.m^{-3}$ may result in the observed bigger dimensional changes in case of 22 mm thick boards.

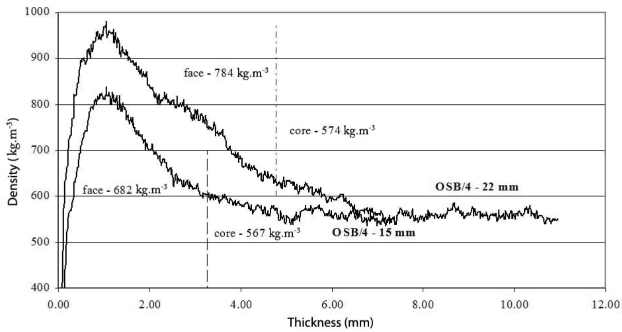

Fig. 1: Vertical density profiles of OSB/4 22 mm and 15 mm.

Relative change in length determined after the first stage for batch no. 1 was -0.43 ÷ -0.49 $mm.m^{-1}$ for the longer axis and -0.55 ÷ -0.68 $mm.m^{-1}$ for the shorter axis, with slightly higher values being recorded for boards with a thickness of 22 mm. In the next stage of analyses samples were subjected to the process of adsorption of moisture from the air and relative change in length recorded after this stage corresponds to the dimensional change determined according to standard EN 318 2008. The smallest relative change in length was observed for the longer axis of board with a thickness of 22 mm and it was by 0.14 $mm.m^{-1}$ smaller than that recorded for board with a thickness of 15 mm for the same axis. Much bigger changes, comparable for both board thickness levels were found for the shorter axis.

In turn, samples in batch no. 2 in the first stage of analyses were subjected to the moistening process. As it results from tests conducted in this respect, a change of relative humidity from 65 to 85 % caused a rather big change in the relative change in length for both board thickness levels, tested along the shorter axis, since they were over 1 $mm.m^{-1}$. However, in the successive stages of conditioning, in which adsorption changes take place, these values are reduced and after stage V of tests they did not exceed 0.86 $mm.m^{-1}$. Also in case of desorption changes the changes in length observed after stage VI of conditioning were smaller than after stage II.

Standard EN 12872 2000 defines maximum changes in linear dimensions of OSB/4 at a change in their moisture content by 1 %. Thus, for the longer axis these changes should not exceed 0.2 $mm.m^{-1}$, while for the shorter axis it should be max. 0.3 $mm.m^{-1}$. As it results from data shown in Figs. 2 and 3, irrespective of board thickness board and testing direction, in case of adsorption processes boards met the requirements of the above mentioned standard. In turn, in case of desorption changes, except for board with a thickness of 15 mm tested along the shorter axis, these changes were slightly bigger. Thus, they were from 0.21 to 0.28 $mm.m^{-1}$ in case of measurements taken along the longer axis for both thickness levels and 0.31 ÷ 0.38 $mm.m^{-1}$ in case of the shorter axis of a 22 mm thick board. Moreover, it needs to be stressed that mean moisture content of boards was 5.9, 8.4 and 16.6 % for boards conditioned in air with relative humidity of 30, 65 and 85 %, respectively. This is consistent with generally accepted assumptions that boards conditioned under these conditions should have moisture contents amounting to 5, 10 and 15 ±2 %, respectively.

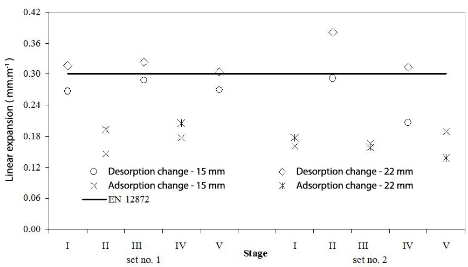

Fig. 2: Relative change in length of OSB/4 per 1 % change in board moisture content – longer axis.

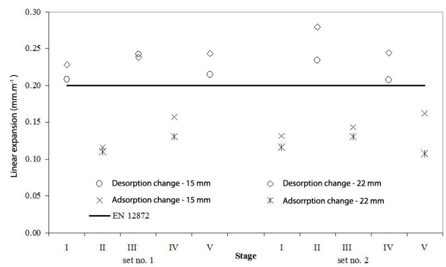

Fig. 3: Relative change in length of OSB/4 per 1 % change in board moisture content – shorter axis.

As a result of sample conditioning in air with relative humidity of 30 % the moisture content of boards decreased by only approx. 2.5 %, while in case of moistening in air with relative humidity of 85 % their moisture content increased by approx. 5 %. It needs to be assumed that as a result of changes in board moisture content occurring during conditioning, a gradual destruction of glue line takes place and thus the effect of the changes occurring in tested boards maybe the observed slight increase in their length after the conditioning period under normal conditions in relation to the initial value (Figs. 4 and 5). Within the range of conducting research this increment is characterized by a rather high value of the goodness of fit coefficient r^2 with a regression curve with a general equation:

$$L = L_1 + a_{(1)}\ln_{(d)} \qquad (3)$$

where: L – length of sample,
L_1 – initial length of sample,
d – cycle of measurement (degree $d = n = 1, 3, 5, 7, 9$),
$a_{(1)}$ – characteristic – value dependent on the direction of changes in moisture content, axis and properties of the wood-based material itself.

Thus is may be expected that for majority of the measurement cycles magnitude of the distortions will be getting smaller and a fitting would assume the exponential shape.

Heterogeneity of material subjected to conditioning makes it difficult to determine coefficients when modelling the phenomenon of dimensional changes occurring during changes in humidity. In case of analyzed OSB subjected to cyclical changes in humidity when determining parameters it would be necessary to take into consideration at least board thickness, board density

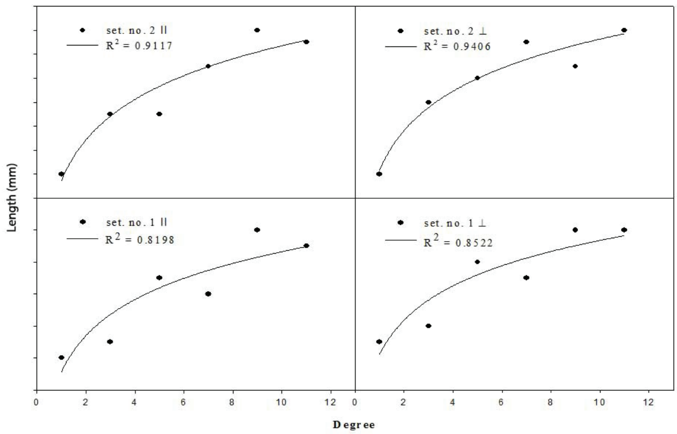

Fig. 4: Length of OSB/4 with a thickness of 15 mm after conditioning in air at 20°C and relative humidity of 65 %

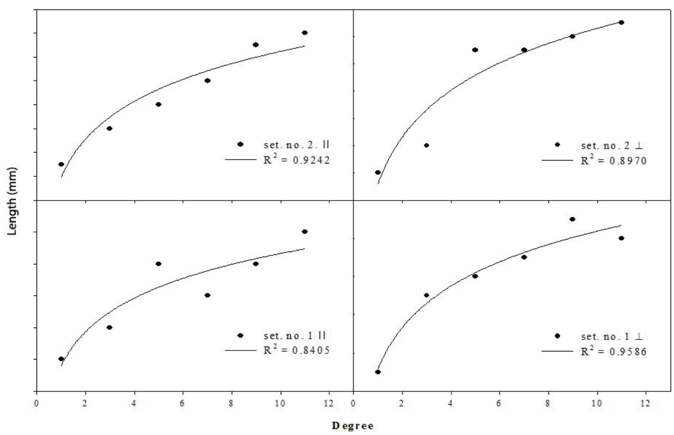

Fig. 5: The effect of cyclically changing humidity at 20°C on length of OSB/4 with a thickness of 22 mm after conditioning in air with relative humidity of 65 %

or the density of layers, the type of adhesive, chip orientation, etc. Most models generally take into consideration one characteristic of the analyzed material, most frequently its density or moisture content, or refer to unidirectional changes in moisture content. However, in this study no direct dependence was found between board density and relative change in length, at the action of cyclically changing relative humidity.

Relative changes in length of boards, calculated in relation to the initial length under the influence of conditioning according to the adopted schedule, are presented in Fig. 6. The lowest value of thus determined relative change in length was recorded for board with a thickness of 22 mm, determined along the longer axis for batch no. 1. Increment in length in this case was 0.13 mm.m^{-1}. In the other variants these values were approx. 0.24 mm.m^{-1} for batch no. 1 and 0.38 mm.m^{-1} for batch no. 2.

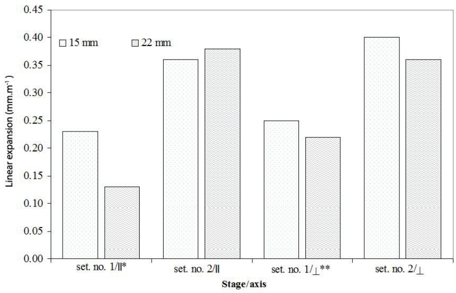

Fig. 6: Relative change in length of OSB/4 determined after the 11th degree of conditioning (- II – longer axis, ** - ⊥ - shorter axis).*

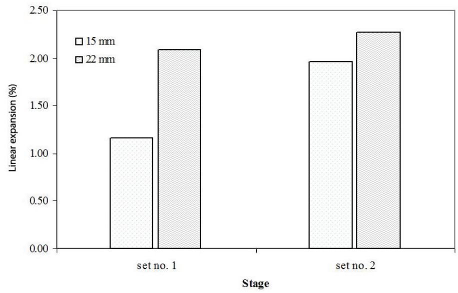

Fig. 7: Relative change in thickness of OSB/4 determined after the 11th degree of conditioning.

The values of relative change in thickness and changes of this thickness per 1 % change in absolute moisture content of OSB/4 used in the analyses are given in Tab. 4. It results from these data that a change in relative humidity in batch no. 1 much more intensively affected changes in thickness than those in length of OSB. In case of desorption changes the relative change in thickness ranged from -0.69 ÷ -1.98 % and 1.77 ÷ 3.78 % for absorption changes, with higher values recorded for boards with a thickness of 15 mm. However, when calculating the value of relative change in thickness per 1 % change in absolute moisture content of the board it turned out that only for batch no. 1 the values recorded for board with a thickness of 15 mm were higher than those recorded for board with a thickness of 22 mm.

Tab. 5: Changes in thickness of OSB/4 occurring under the influence of changes in relative humidity.

Stage	Change in humidity	15 mm			22 mm		
		Relative change in thickness	Standard deviation	Change in thickness / change in humidity	Relative change in thickness	Standard deviation	Change in thickness / change in humidity
	(%)	δt (%)	σ (%)	$\delta_{t/\%}$ (%/%)	δt (%)	σ (%)	$\delta_{t/\%}$ (%/%)
Set no. 1							
I	65→30	-0.84	0.17	-0.41	-0.65	0.12	-0.30
II	65→85	3.35	0.25	0.53	3.18	0.13	0.57
III	65→30	-1.98	0.17	-0.69	-1.36	0.10	-0.58
IV	65→85	2.62	0.22	0.56	2.29	0.21	0.40
V	65→30	-1.91	0.16	-0.61	-1.22	0.07	-0.44
Set no. 2							
I	65→85	3.78	0.53	0.60	3.61	0.15	0.63
II	65→30	-1.03	0.12	-0.40	-0.91	0.11	-0.40
III	65→85	2.12	0.13	0.41	1.82	0.27	0.42
IV	65→30	-1.02	0.12	-0.38	-0.95	0.12	-0.39
V	65→85	1.80	0.14	0.40	1.77	0.17	0.39

In batch no. 2 such presented values of relative change in thickness were almost identical for both boards. It turned out that in case of board thickness a significant role is played by the order of changes in the action of air. Samples from batch no. 1 in the first stage were subjected to desorption and for this stage they met the requirement of standard EN 12872 2000, while for successive stages, except for board with a thickness of 22 mm for stages III and IV, recorded values were higher than 0.5 %. An opposite dependence was found for batch no. 2. In this case after the zero stage, i.e. adsorption change, boards did not meet requirements of the standard, while for successive stages, irrespective of board thickness or the direction of changes in moisture content, these values fluctuated around 0.4 % and they were by 20 % lower than those required by the standard.

Despite bigger periodical changes and similar values of relative change in thickness per a 1 % change in board moisture content, boards with a thickness of 15 mm turned out to be more stable dimensionally after undergoing 11 degrees of conditioning (Fig. 7, Tab. 5).

CONCLUSIONS

As a result of conducted analyses it was found that relative changes in length of OSB/4 to a much higher degree depend on the course of changes in relative humidity than on their thickness. The decisive factor affecting the volume of recorded values in this case seems to be the orientation of chips. In turn, relative change in length per 1 % change in moisture content of tested boards was generally proportional to board thickness, since the observed relative change in length of board with a thickness of 22 mm was by around a dozen percent bigger than that for board with a thickness of 15 mm. As a result of cyclical changes in moisture content the length of boards increased in relation to their initial length, irrespective of the direction of changing moisture content. Recorded final values of relative change in length in relation to the first degree were approx. 0.24 $mm.m^{-1}$ for board from batch no. 1 and 0.38 $mm.m^{-1}$ for batch no. 2. In turn, relative change in thickness for OSB/4 calculated for individual stages was inversely proportional to their thickness; however, boards with a thickness of 22 mm were characterized by a higher increase in thickness after the 11th degree of conditioning, calculated in relation to stage I.

ACKNOWLEDGMENT

This study was financed by the Polish Ministry of Science and Higher Education, grant number N N309 428138.

REFERENCES

1. Ayrilmis, N., 2007: Effect of panel density on dimensional stability of medium and high density fiberboards. J. Mater. Sci. 42(20): 8551-8557.
2. Constant, T., Badia, M.A., Mothe, F., 2003: Dimensional stability of Douglas fir and mixed beech-poplar plywood: Experimental measurements and simulations. Wood Sci. Technol. 37(1): 11-28.
3. Kelly, M.W., 1977: Critical literature review of relationship between processing parameters and physical properties of particleboard. Gen. Tech Rep. FPL-10. USDA Forest Service, Forest Products Laboratory, Madison Wis.. Pp 65.

4. Mirski, R., Derkowski, A., Łęcka, J., 2007: The effect of ambient conditions on dimensional stability of OSB/3. Ann. Warsaw Agricult. Univ.-SGGW, For. Wood Technol. 62: 40-48.
5. Pugel, A.D., Price, E.W., Hse, C.Y., 1990: Composites from suthern pine juvenile wood. Part 2. Durability and dimensional stability. For. Prod. J. 40(3): 57-61.
6. Sekino, N., Shibusawa, T., 2002: Hygroscopic linear expansion of wood-based panels under mechanical restraint with nailing and/or bonding. Wood Industry 57(2): 57-62 (in Japanese).
7. Suchsland, O., 1972: Linear hygroscopic expansion of selected commercial particleboards. For. Prod. J. 22(11): 28-32.
8. Suzuki, S., Miyamoto, K., 1998: Effect of manufacturing parameters on the linear expansion and density profile of particleboard. J. Wood Sci. 44(6): 444-450.
9. Wu, Q., Suchsland, O., 1996: Linear expansion and its relationship to moisture content change for commercial oriented strandboards. For. Prod. J. 46(11/12): 79-83.

Radosław Mirski, Dorota Dziurka
Poznań University of Life Sciences
Department of Wood-Based Materials
Wojska Polskiego Str. 28
60-637 Poznań
Poland
Corresponding author: rmirski@up.poznan.pl