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FORM AND MASS CHANGES OF COMPOSITE PANELS UNDER VARIABLE ENVIRONMENT HUMIDITY

The aim of this study was to determine the influence of relative humidity on the form and mass of composite panels produced from wood-based panels covered with aluminium plate on one side. Part of the samples was additionally covered with aluminium foil on the side opposite to aluminium plate. HDFs, MDFs and particleboards were used as base material. The results of experiments show that relative humidity changes cause geometrical deformations and mass changes of composite fibre-based panels. The largest permanent form changes (i.e. that remained after the cycle of air relative humidity changes was finished) were observed for material moderately reacting to humidity changes.

Keywords: composite, wood-based panel, HDF, MDF, particleboard, aluminium plate, relative humidity, form

Introduction

Modern furniture designers and producers are seeking new materials that are rarely used in furniture production today. Firstly, the intention is to create an

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outstanding and innovative product. On the other hand, the objective can be also reduction of furniture part thickness, while the strength needed for safe use of the final product is retained. An example of such material can be the composite of wood-based panel and aluminium plate. It is easy to imagine shelves or side walls of furniture made of wood-based panels covered with a thin aluminium plate on one side or both sides. Even if the concept is rather simple, there are many engineering problems connected with such composites, including bonding method for two different materials or optimisation of strength/thickness ratio. Performance of this kind of composites under variable environmental and exploitation conditions (such as humidity) must be investigated, especially if asymmetrical use of the aluminium component is considered.

Hammoum and Audebert's [1999] model of (visco)-plastic behaviour of wood under moisture change is useful to modelling of stresses of wooden structural elements exposed to variable humidity using the finite elements method. This model is not useful in the case of wood-based panels covered with aluminium plate on one side. The investigations conducted by Ganev et al. [2003] show that the equilibrium between environment humidity and moisture content increase with MDF density increase. According to Niemz and Poblete [1996] the degree of MDF swelling under variable humidity is lower than respective values for particleboards. There is a gap in information on behaviour of the wood-based panel – aluminium plate composite under variable environment humidity.

The aim of the investigations was to determine the influence of environment relative humidity on the form and mass of composite panels made of wood-based panels one-sidedly covered with aluminium plate.

Materials and methods

Materials

In the tests 8 different wood-based panels were used as a base of the composite: 2 different thicknesses of fibreboard (HDF), 5 different thicknesses of particleboard, including 2 types of particleboard produced from poplar wood, and one MDF panel. The specification of the panels is presented in table 1.

Composites of the dimensions of 500 × 500 mm were produced. A 0.5 mm thick aluminium plate as well as aluminium foil (the so-called "kitchen foil") were used for part of the samples. The narrow surfaces of all samples of the composite were uncovered. To glue the aluminium plates to the panels Henkel Terostat-MS 930 glue was used. This adhesive is an industrial sealant based on modified silane polymers. On applying glue on the elements, they were joined together in a cold press keeping the parameters recommended by the glue producer.

Table 1. The specification of panels used as base material in composites
Tabela 1. Specyfikacja płyt użytych jako materiał bazowy w kompozytach

Marking *Oznaczenie*	Panel type *Rodzaj płyty*	Thickness [mm] *Grubość [mm]*
1	fibreboard (HDF) *płyta pilśniowa (HDF)*	4
2	fibreboard (HDF) *płyta pilśniowa (HDF)*	6
3	particleboard *płyta wiórowa*	6
4	particleboard *płyta wiórowa*	8
5	particleboard *płyta wiórowa*	10
6	(poplar) particleboard *płyta wiórowa z wiórów topolowych*	10
7	(poplar) particleboard *płyta wiórowa z wiórów topolowych*	14
8	fibreboard (MDF) *płyta pilśniowa (MDF)*	15

a) b)

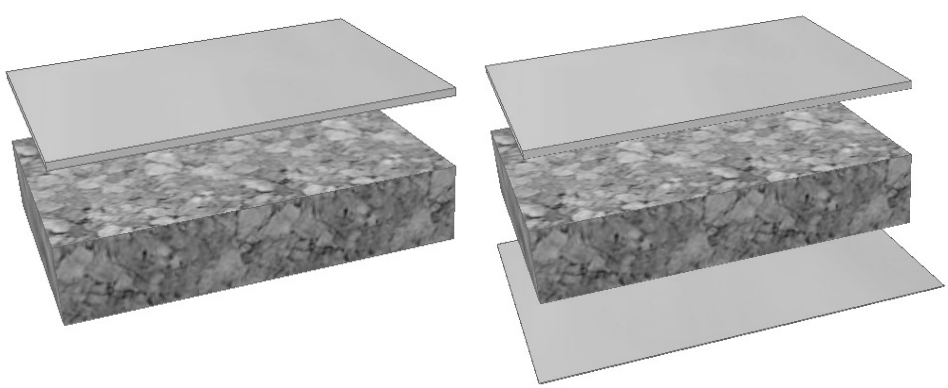

Fig. 1. Construction of the composite of aluminium and wood-based panel: a) composite without aluminium foil; b) composite with aluminium foil
Rys. 1. Konstrukcja kompozytu aluminium-płyta drewnopochodna: a) kompozyt bez folii aluminiowej; b) kompozyt z folią aluminiową

Methods

The 500 × 50 mm samples of the composite materials were stored in a climate room in the temperature of 20°C. The samples were put in special tight boxes equipped with fans to move the air inside the boxes. On the bottom of the boxes different water solutions (e.g. saturated solution of table salt) were placed to achieve the assumed environment relative humidity.

Table 2. Phases of changes in storage conditions of tested material
Tabela 2. Etapy zmian warunków przechowywania badanego materiału

Phase *Etap*	Duration [days] *Czas trwania [doba]*	Environment relative humidity [%] *Wilgotność względna otoczenia [%]*
1	7	room humidity *wilgotność otoczenia*
2	7	60
3	7	76
4	7	44
5	7	60

A simple but effective stand with Mitutoyo digital gauge was used to measure deflection of the samples (fig. 2). The span between supports was 450 mm and the digital gauge was placed in the middle of the span. The digital gauge accuracy was 0.01 mm. Data from the gauge was collected in the computer. Before each cycle of measurements the device was reset to zero on a Mitutoyo laboratory standard flat surface in natural seasoned granite stone (certified free from significant deterioration or dimensional change over time). During the measurement the surface covered with aluminium plate was directed towards the

Fig. 2. A sample's deflection measurement
Rys. 2. Pomiar zniekształcenia próbki

measuring device (the uncovered/aluminium foil covered surface was opposite to the measuring device). A positive deflection value means sample convexity and negative deflection value (–) means sample concavity.

Results and discussion

The results of measurements of deflection of samples not covered with aluminium foil after their storage under different environment relative humidity are shown in fig. 3. The largest total deflection (the largest minus room humidity deflection) was observed for thin fibreboards (no. 1 and 2: deflection –23.38 and –22.27 mm, respectively), and the smallest for MDF panel (no. 8: –2.44 mm). Thin fibreboards and thin particleboards also were characterised by the largest residual deflection after the last phase of storage (compared to the first phase of storage under 60% relative humidity – r.h.): from –6.96 mm for sample no. 2 to –5.69 mm for sample no. 4. The smallest residual deflection was observed for MDF panel (no. 8: –0.38 mm) and for sample no. 1 (–0.36 mm). Interestingly, after the last phase of the cycle (60% r.h.) all tested samples were characterised by final deflection larger than the deflection observed after the first phase of storage under the same humidity conditions without getting back to the previous shape. However, on comparing the relative residual deflection, calculated as residual/maximal deflection ratio, it was noted that samples with average values of maximal deflection were characterised by the highest residual/maximal deflection ratio: sample no. 4 – 56%, sample no. 6 – 35%. In this case sample no. 1 was characterised by the smallest value of the above-mentioned ratio, i.e. 2%. The smaller deflection of the 15 mm thick MDF (sample no. 8) compared to 14 mm thick particleboard (sample no. 7) confirms Niemz and Poblete's [1996] conclusion that the degree of swelling of MDF under variable humidity is lower than the respective values for particleboards.

The results of measurements of deflection of samples covered with aluminium foil after their storage under different environment relative humidity are presented in fig. 4. The largest relative deflection (the largest minus room humidity deflection) was observed for thin fibreboards and thin particleboards: –14.38 mm for sample no. 1 and –11.87 mm for sample no. 4. The smallest relative deflection was noted for sample no. 7 –2.76 mm and no. 8 –3.07 mm. The largest residual deflection (after the last phase of storage under 60% r.h. compared to the first phase of storage under that r.h.) was observed for sample no. 3 (–6.04 mm) and the smallest residual deflection for sample no. 7 (–0.49 mm). The relative residual deflection was also the highest (for samples not covered with aluminium foil) in the case of panels characterised by average maximal deflection, i.e. sample no. 5 – 50% and no. 3 –43%, and the smallest for samples no. 7 –18% and 8 –21%.

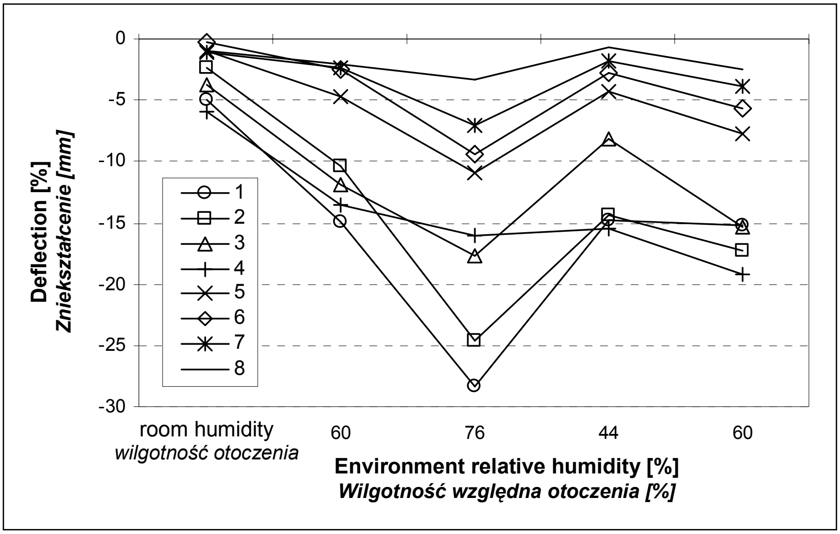

Fig. 3. Deflection of samples not covered with aluminium foil stored in variable environment relative humidity

Rys. 3. Zniekształcenie próbek niepokrytych folią aluminiową przechowywanych w zmiennych warunkach względnej wilgotności powietrza

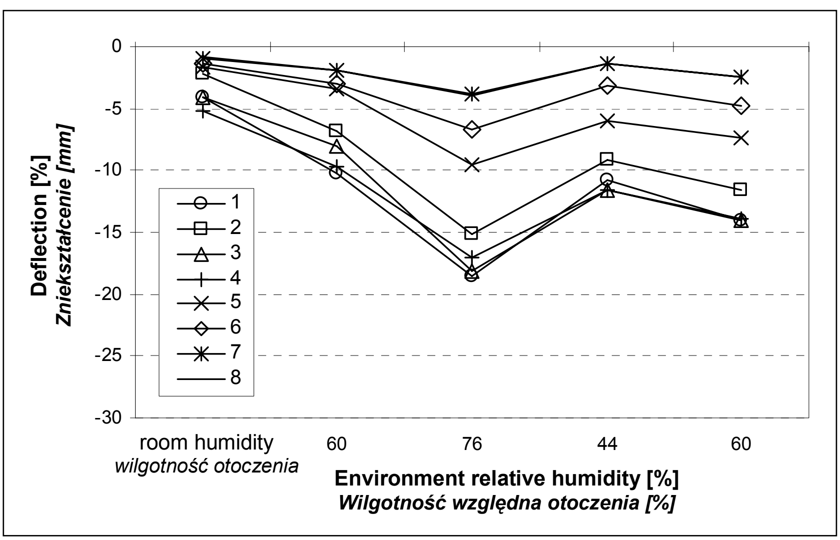

Fig. 4. Deflection of samples covered with aluminium foil stored in variable environment relative humidity

Rys. 4. Zniekształcenie próbek pokrytych folią aluminiową przechowywanych w zmiennych warunkach względnej wilgotności powietrza

Relative mass changes (compared to the initial mass) of samples not covered with aluminium foil stored in variable environment relative humidity are displayed in fig 5. Samples produced from fibres were characterised by the largest mass changes (samples no. 1, 2) like thin particleboards (sample no. 4). Thicker panels were more resistant to mass change (sample no. 6). After all changes of the environment relative humidity the mass of the samples was bigger than before.

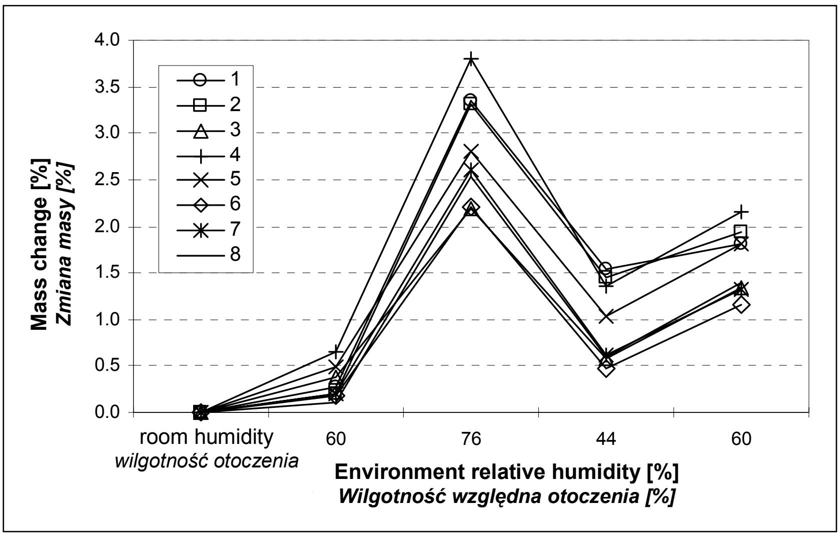

Fig. 5. Mass changes of samples not covered by aluminium foil stored in variable environment relative humidity
Rys. 5. Zmiana masy próbek niepokrytych folią aluminiową przechowywanych w zmiennych warunkach względnej wilgotności powietrza

Relative mass changes (compared to the initial mass) of samples not covered with aluminium foil stored in variable environment relative humidity are displayed in fig. 6. In this case panels produced from fibreboards and thin particleboards were more susceptible to mass changes (samples no. 2, 4, 5 and 8). The smallest mass changes were observed for 10 and 14 mm thick poplar particleboard.

Fig. 7 presents comparison of maximum mass changes of samples covered and uncovered with aluminium foil stored in variable environment relative humidity. The general tendency of panels produced from fibres towards high mass changes is confirmed. Also sample no. 4 (8 mm thick particleboard) was characterised by high moisture uptake. The influence of the aluminium foil cover is clearly visible: except sample no. 8 all covered samples were characterised by smaller mass changes compared to uncovered samples.

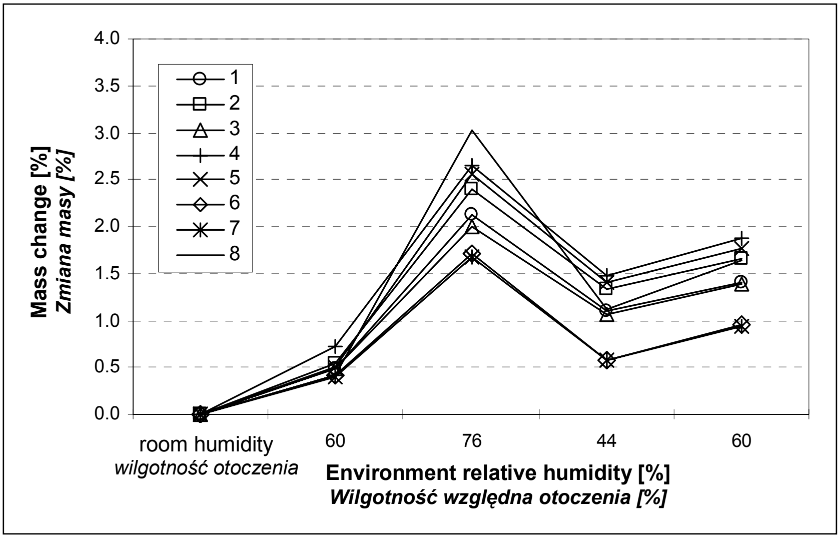

Fig. 6. Mass changes of samples covered with aluminium foil stored in variable environment relative humidity
Rys. 6. Zmiana masy próbek pokrytych folią aluminiową przechowywanych w zmiennych warunkach względnej wilgotności powietrza

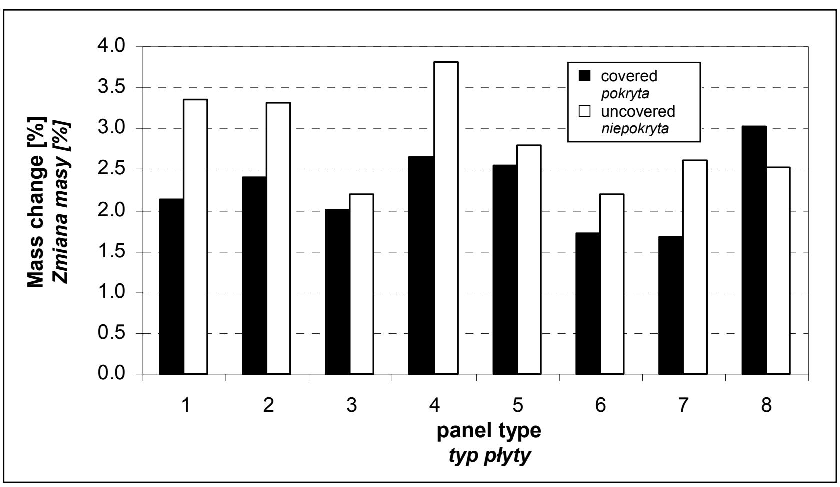

Fig. 7. Comparison of maximum mass changes of samples covered and uncovered with aluminium foil stored in variable environment relative humidity
Rys. 7. Porównanie maksymalnej zmiany masy próbek pokrytych i niepokrytych folią aluminiową przechowywanych w zmiennych warunkach względnej wilgotności powietrza

Conclusions

Conducted research shows that there is a general tendency that samples produced from fibres are characterised by bigger deflection and mass changes after storage under different environment relative humidity. Interestingly, samples with average deflection were characterised by the largest relative residual deflection. Covering of samples with aluminium foil causes smaller changes of samples' shape and mass under different environment relative humidity changes, however, those changes still exist.

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ZMIANY KSZTAŁTU I MASY PŁYT KOMPOZYTOWYCH POD WPŁYWEM ZMIENNEJ WILGOTNOŚCI OTOCZENIA

Streszczenie

Celem badań było określenie wpływu zmian względnej wilgotności otoczenia na kształt i masę płyt kompozytowych, wytworzonych z płyt drewnopochodnych jednostronnie pokrytych blachą aluminiową. Część próbek po stronie przeciwległej do blachy aluminiowej pokryto folią aluminiową. Jako materiał bazowy zostały użyte płyty HDF, MDF oraz płyty wiórowe. Badania wykazały, iż zmiana względnej wilgotności otoczenia wywołuje największe zmiany kształtu i masy w materiałach opartych na płytach włóknistych (HDF oraz MDF). Największe resztkowe zmiany kształtu (trwałe po zakończeniu całego cyklu zmian wilgotności) towarzyszyły materiałom, które na owe zmiany wilgotności reagowały z przeciętną intensywnością.

Słowa kluczowe: kompozyt, płyta drewnopochodna, HDF, MDF, płyta wiórowa, blacha aluminiowa, wilgotność względna, kształt