Springback in Acetylated Wood Based Composites

Behbood Mohebby[1], Maryam Gorbani-Kokandeh[2], Mojtaba Soltani[3]

[1]Dep. of Wood & Paper Sciences, Faculty of Natural Resources, Tarbiat Modares University, P.O. Box 46414-356, Noor, Iran [mohebbyb@modares.ac.ir ; W: www.tmu.ir/wood]

[2]Dep. of Wood & Paper Sciences, Faculty of Natural Resources, Mazandaran University, Sari, Iran

[3]Dep. of Wood & Paper Sciences, Azad University, Chaloos, Iran

Keywords: acetylation, medium density fibreboard (MDF), particleboards (PB), spring back

ABSTRACT

Reasons of loss in strengths of acetylated wood based composites were still under question. This research was considered to study springback in acetylated particleboard and medium density fibreboard. Chips and fibres were acetylated by using acetic anhydride to gain different percentage of acetylation (WPG). Boards were made based on target thicknesses. Thickness of the boards as well as moduli of elasticity and rupture was determined after conditioning at room temperature and relative humidity of 65%. Results showed increase of the thickness in the test boards after conditioning. It was revealed that the springback was correlated with the weight gain and it was increased as the WPG was raised in the test boards.

INTRODUCTION

Advantages of the acetylation have been reported by many authors. The wood and the wood based composites become moisture repellent due to due to the acetylation reaction (Rowell 1983, 1996). The reaction is accompanied by substitution of hydrophilic hydroxyl groups by hydrophobic acetyl groups in wood cell wall polymers and causes increase in bioresistance (Nilsson *et al*. 1988, Takahashi *et al*. 1989, Militz 1991, Larsson-Brelid 1997, Ibach *et al*. 2000, Mohebby 2003); resistance against weathering (Evans et al., 2000) and decrease in board roughness (Evans *et al*. 2000), reduction in moisture absorption (Rowell *et al*. 1988, Rowell *et al*. 1989, Ohmae *et al*. 2002, Mohebby and Hadjhassani 2008). In spite of those advantages, there are different reports indicating that the mechanical strengths are diminished in the acetylated wood based composites (Rowell *et al*. 1988, Rowell *et al*. 1989, Rowell 1996, Fuwape and Oyagade 2000, Mahlberg 2001). There are different opinions to explain reasons of the strength loss; *e.g*. type of adhesive (Vick and Krzysik, 1991), less press pressure, *etc*. It has been proposed to apply higher press pressure to increase the strengths (Rowell *et al*., 1988, 1989, Rowell 1996). However, no report has paid detailed attention to springback in the acetylated composites and relationship with the strength losses. It is known that the springback in the wood based composites occurs usually after manufacture of the boards. Springback is an irreversible thickness swelling which occurs after wetting of the composites and is attributed to the release of applied stresses accompanied by some loss of glue bonds (Geimer and Price 1978, Palardy *et al*. 1989). Springback indicates debonding of adhesion between wood elements and adhesives. Result of debonding in the boards is loss of the strengths (River 1994), which occurs in the specimens subjected to different exposures because of a lowering of board density (River 1994). The mechanical properties that were presumably most directly affected by the springback are

the shear strength, the modulus of elasticity, and the modulus of rupture because these properties depend somewhat on the strength that is developed by the mechanical interlocking of the compressed particles in the composites (Hann 1963).Current research was focused on relationship between the acetylation and strength changes in the wood based composites, medium density fibreboard (MDF) and particleboard (PB), which is associated with the springback.

EXPERIMENTAL

Acetylation- Poplar wood fibres were provided by Khazarchoob Company, manufacturer of MDF in Iran, and required chips were prepared by a laboratory chipper from Oriental beech wood (*Fagus orientalis* Lipsky). Both fibres and chips were dried in an oven for 24 h at 103±2 °C. Afterwards, the acetylation was carried out in a stainless steel reactor at 120 °C for varying time to obtain different weight percent gains (WPGs). Acetic anhydride was used for the acetylation reaction. Acetylated fibres and chips were washed in rinsed water to remove formed acetic acid as by-product of the reaction. Afterwards, they were oven dried for 24 h to determine the WPGs in the acetylated fibres and chips. The WPGs were determined based on oven dry weights of parallel samples which were treated at the same conditions as the main samples. The WPG was calculated according to equation 1:

$$WPG= (W_{act} – W_{unt}) / W_{unt} \times 100 \quad (1)$$

Where: WPG indicates weight percent gain (%); W_{act} and W_{unt} oven dry weight after and before the acetylation (g), respectively.

Manufacture of boards – Sample boards were made based on required target densities with thicknesses of 10 and 15 mm for MDF and PB, respectively. Urea formaldehyde (UF) was applied as resin for 10% based on oven dry weights of the used fibres and chips in the board mats. Pressure (30 bar) was applied at press temperature of 170 °C for 10 min.

Tests- Afterwards, the boards were conditioned at room temperature and a relative humidity of 65% for two weeks. Thickness of the boards was measured at least at three points of the boards. Five boards were made for any WPG. The springback was determined according to Eqn. 2.

$$S = (T_1 – T_0) / T_0 \times 100 \quad (2)$$

Where: S indicates springback of the board (%); T_1 and T_0 indicate board thicknesses after and before the conditioning (mm), respectively. The boards were cut into required sizes for static bending test according to DIN 98754-1. Moduli of elasticity (MOE) and rapture (MOR) were determined based on the bending test.

RESULTS

Determination of the moisture content (MC) in the acetylated boards after th conditioning showed that the MC was reduced as the WPG increased (Fig. 1). It was also revealed that the acetylation affected thickness swelling of the boards (Fig. 2) and

caused significant reduction as the WPG increased in the boards when they were soaked in the water.

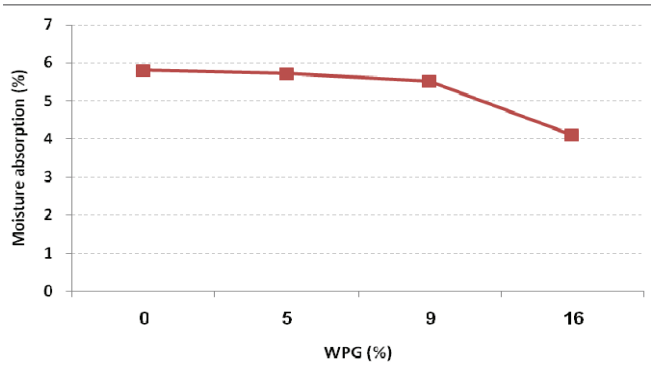

Figure 1: Moisture absorption in acetylated particleboard during conditioning

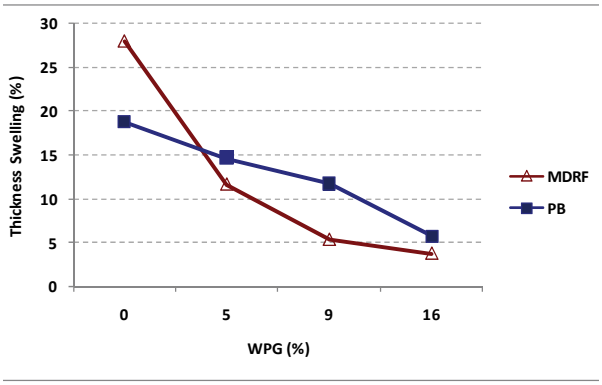

Figure 2: Thickness swelling in acetylated boards after 24h of soaking in water; PB: particleboard, MDF: medium density fibreboard

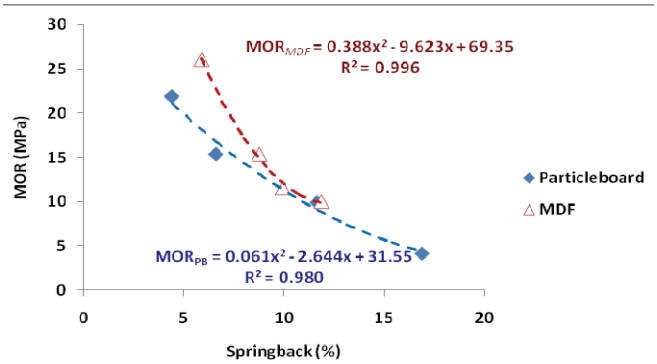

Figure 3: Correlation between springback and modulus of rupture in acetylated particleboard (PB) and medium density fibreboard (MDF)

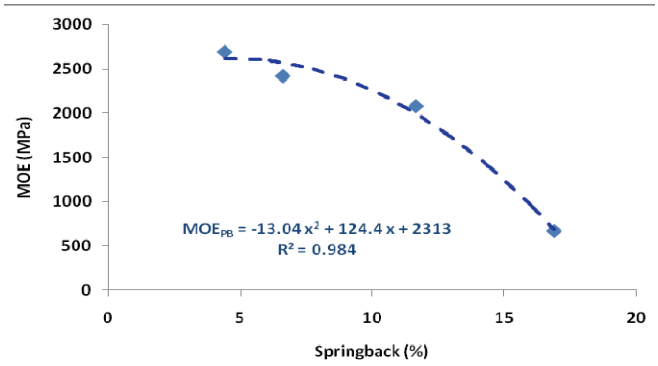

Figure 4: Correlation between springback and modulus of elasticity in acetylated particleboard (PB)

Determination of correlation between the springback and the MOR in the acetylated boards is shown in Fig. 3. It was determined that increase of the springback in the acetylated boards caused significant loss in the MOR. As it is shown in the Fig. 3, coefficient of the determination (R^2) was 0.996 and 0.980 for the particleboard (PB) and the medium density fibreboard (MDF), respectively. The results indicated that the springback reduced the MOR in the acetylated boards. Comparison between both boards revealed higher influence of the springback on the MOR loss of the MDF. Results also revealed high correlation (R^2= 0.984) between the modulus of elasticity (MOE) of the particleboard and the springback (Fig. 4). According to the results, increase of the springback reduced the MOE in the acetylated particleboard. Fig. 5 shows correlation between the WPG and the springback in the acetylated boards. As it has shown, increase of the WPG caused increase of the springback with higher coefficient of the determination (0.979 for the PB and 0.995 for the MDF). According to above results, it could be expressed that the acetylation affected severely the springback of the acetylated particleboard than the acetylated MDF.

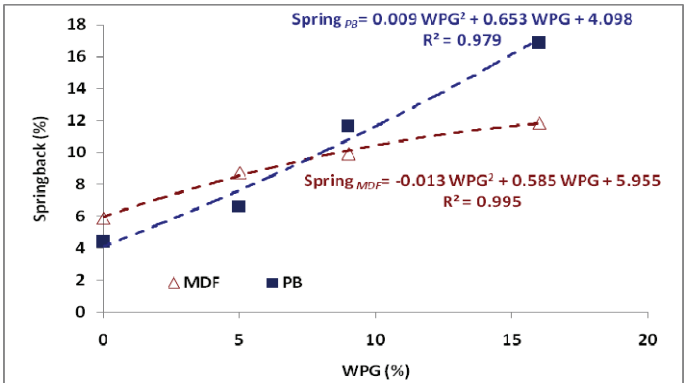

Figure 5: Correlation between weight percent gain (WPGs) and springback in acetylated particleboard (PB) and medium density fibreboard (MDF)

DISCUSSION

Acetylation caused the boards to absorb less moisture during the conditioning and become more stable dimensionally. Also the acetylated boards do not swell severely when they are exposed to the water as the untreated one. Dimensional stability of the boards during the conditioning was a good indication of the acetylation effect on the thickness changes. The moisture could not affect the boards and cause significant variation in the springback. However, the moduli of elasticity and rupture were significantly affected by the acetylation. The results also showed that the acetylation affected significantly the springback of the boards with springback highly correlated with the WPGs of the boards. High correlation between the springback and the strength losses of the boards are related to the acetylation and resulted debonding of the wood elements. The springback is an indication of the debonding of the wood elements and stress relief (River 1994). According to Sanders *et al*. (2003), the acetylation causes bulking of the wood cell walls. Acetylated materials become denser and stiffer materials according to authors' observation. Those materials resist against applied stresses during pressing of the board's matt. After opening the press, accumulated stresses are gradually relieved. Stronger bonding due suitable resins could cease the stress relief in the composites. However, application of aqueous-based resins interfere bonding between the wood elements due to low wettability according to reports (Vick and Rowell 1990, Vick and Krzysik 1991). As the urea formaldehyde resin was used here to bond the acetylated wood elements; it is likely that the acetylation interfered with adhesion of the aqueous-based adhesive and could not properly bond the wood fibres and the chips depending on level of the acetylation and caused strength losses in the acetylated composites. Vick and Rowell (1990) reported also interfere between the acetylation and the aqueous-based adhesives. Vick *et al*. (1991) reported loss of the MOE and the MOR in acetylated flakeboard.

DISCUSSION

Results of the current research showed that the strength loss in the acetylated composites is highly correlated with the springback. And the springback itself is also significantly depended to the extent of the acetylation and causes loss of the strengths followed by the WPG increase.

REFERENCES

Deutsches Institut für Normung, DIN 68754-1 (1976). Harte und mittelharte Holzfaserplatten für das Bauwesen – Holzwerkstoffklasse.

Evans, P.D., Wallis, F.A. and Owen, N.L. (2000). Weathering of Chemically Modified Wood Surfaces: Natural Weathering of Scots Pine Acetylated to Different Weight Gains. *Wood Science & Technology*, Vol. 34, 151-165.

Fuwape, J.A. and Oyagade, A.O. (2000). Strength and Dimensional Stability of Acetylated *Gamelina* and Spruce Particleboard. *Journal of Tropical Forest Products,* 6(2): 184-189.

Geimer, R.L. and Price, E.W. (1978). Construction Variables Considered in Fabrication of a Structural Flakeboard. *Proceedings of Construction Variables in Fabrication*, June 6-8. Kamzas. USA.

Hann, R.A., Black, J.M. and Blomquist, R.F. (1963). How Durable is Particleboard? Part II: The Effect of Temperature and Humidity. *Forest Products Journal.*, Vol. 8 (5), 169-174.

Ibach, R.E., Hadi, Y.S., Nandika, D., Yusuf, S. and Indrayani, Y. (2000). Termite and Fungal Resistance in Situ Polymerized Tributyltin Acrylate and Acetylated Indonesian and USA Wood. *The International Research Group on Wood Preservation*, Document No. IRG/WP 00-30219.

Larsson-Brield, P., Simonson, R. and Bergman, O. (1997). Resistance of Acetylated Wood to Biological Degradation: Evaluation of Field Test. *The International Research Group on Wood Preservation.* Document, No. IRG/WP 97-30139.

Mahlberg, R., Paajanen, L., Nurmi, A., Kivisto, A. and Rowell, R.M. (2001). Effect of Chemical Modification of Wood on the Mechanical and Adhesion Properties of Wood Fibre / Polypropylene Fibre and Polypropylene / Veneer Composites. *Holz als Roh- und Werkstoff*, 59, 319-326.

Militz, H. (1991). Die Verbesserung des Schwind- und Quellverhaltens und der Dauerhaftigkeit von Holz mittels Behandlung mit unkalalysiertem Essigsäureanhydrid. *Holz als Roh- und Werksttoff*, 49, 147-152.

Mohebby, B. (2003). Biological Attack of Acetylated Wood. *Ph.D. Thesis. Göttingen University. Göttingen. Germany*, P. 167.

Mohebby, B. and Hadjhassani, R. (2008). Moisture Repellent Effect of Acetylation on Poplar Fibres. *J. Agric. Sci. Technol*., **10** , 157-163.

Nilsson, T., Rowell, R.M., Simonson, R. and Tillman, A.M. (1988). Fungal Resistance of Pine Particleboards Made from Various Types of Acetylated Chips. *Holzforschung*, **42**, 123-126.

Ohmae, K., Minato, K. and Norimoto, M. (2002). The Analysis of Dimensional Changes due to Chemical Treatment and Water Soaking for Hinoki (*Chamaecyparis obusta*) Wood. *Holzforschung*, **56**, 98-102.

Palardy, R.D., Haataja, B.A., Shaler, S.M., Williams, A.D. and Laufenberg, T.L. (1989). Pressing of Wood Composite Panels at Moderate Temperature and High Moisture Content. *Forest Products Journal,* **39**, 27-32.

River, B.H. (1994). Outdoor Aging of Wood-Based Panels and Correlation with Laboratory Aging. *Forest Products Journal*, **44**, 55-65.

Rowell, R.M., Youngquist, J.A., Imamura, Y. (1988). Strength Test on Acetylated Aspen Flakeboards Exposed to a Brown Rot Fungus. *Wood and Fibre Science*, **20**, 266-271.

Rowell, R.M. (1983). Chemical Modification of Wood. *Forest Products Abstracts*, **4**, 363-382.

Rowell, R.M. (1996). Physical and Mechanical Properties of Chemically Modified Wood. In: Hon D.N.S.: *Chemical Modification of Lignocellulosic Materials.* Marcel Dekker. New York. pp. 295-310.

Rowell, R.M., Kawai, S.I.Y. and Norimoto, M. (1989). Dimensional Stability, Decay Resistance and Mechanical Properties of Veneer-Faced Low-Density Particleboards Made from Acetylated Wood. *Wood and Fibre Science*, **21**, 67-79.

Sander, C., Beckers, E.P.J., Militz, H. and van Veenendaal, W. (2003). Analysis of acetylated wood by electron microscopy. *Wood Science and Technology*, **37**, 39-46.

Takahashi, M., Imamura, Y. and Tanahashi, M. (1989). Effect of Acetylation on Decay Resistance of Wood Against Brown Rot, White Rot and Soft Rot. International Chemistry, *Congress of Pacific Basin Societies, Agrochemistry, Sub-symposium on Chemical Modification of Lignocellulosic Materials-Chemical Reactions*, p. 16.

Vick, C.B., Krzysik, A. and Wood, Jr. J.E. (1991). Acetylated, Isocyanate-Bonded Flakeboards after Accelerated Aging: Dimensional Stability and Mechanical Properties, *Holz als Roh-und Werkstoff*, **49**, 221-228.

Vick, C.B. and Rowell, R.M. (1990). Adhesive bonding of acetylated wood. *Int. J. Adhesion and Adhesives,* Vol. **10**, 263-272.