# Evaluation of Fracture in Acetylated Wood-Based Composites

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## ABSTRACT

The objective of this study was to investigate the influence of the acetylation on fractures on the medium density fiberboard (MDF). Industrial fibers were acetylated in a reactor at 120 °C, with acetic anhydride and without any catalyst to achieve weight gains 5, 9 and 16 % (WPGs). The test boards were made based on the target density of 0.7 g/cm$^3$, with 10 mm thickness under a pressure of 30 bar at press temperature of 180 °C for 5min. The internal bonding (IB) and the modulus of rupture (MOR) of the boards were determined and fractures were studied with Scanning Electron Microscope (SEM). The results showed that the IB and the MOR were reduced due to the acetylation. Fractures in the failure lines of the untreated samples were revealed as linear, however in the treated samples, the failure lines were recognized as diagonal. The SEM observations indicated that the fractures in the untreated boards are dependent on the adhesive properties and similar to brittle materials; however in the acetylated boards, the fractures are dependent on the behavior of the fibre-adhesive bonds, and similar to supple materials.

## INTRODUCTION

The wood and the wood-based composite are currently known as the one of the best engineering materials for construction. However, the wood based composite resolved different application problems existing in the wood. Besides that, they behave as the wood; for example they are capable to be attacked by the biological agent, the dimensions are changed at moist and dry conditions, and they are also weathered due to UV light.

Chemical modification has been used to improve properties of the wood and its composites. Among the various treatments, the acetylation was the most emphatic and extensive one in applications (Rowell, 1993; Hill, 2006). According to Rowell, 1983, the acetylation is a reaction between acetic anhydride with wood polymers, lignin, cellulose and also hemicelluloses, and the reaction is accompanied by substitution of hydrophilic hydroxyl groups with hydrophobic acetyl groups in the wood cell wall polymers. There are many reports of the advantages of the acetylation. Moisture replellency (Rowell, 1983), reduction in the moisture absorption (Rowell, 1988; Rowell *et al*., 1989; Mohebby and Hadjhassani, 2008), increasing of the durability against biological attacks (Takahashi *et al*., 1989; Larsson *et al*., 1997; Ibach *et al*., 2000; Mohebby, 2003), resistance against the weathering (Evans, 2000). There are also different reports about the mechanical strengths of the acetylated wood based composite

(Rowell, 1988; Rowell *et al.*, 1989) indicated reduction in their strengths. Current research was focused on relationship between acetylation, strength and fracture surfaces.

## EXPERIMENTAL

### *Acetylation*

Poplar wood fibers were provided by Khazarchoob Company, manufacturer of MDF in Iran. Fibers 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. The WPG was calculated according to (Eqn. 1).

$$WPG = (W_{act} - W_{unt}) / W_{unt} \times 100 \qquad (1)$$

Where: WPG indicates weight percent gain (%); $W_{act}$ and $W_{unt}$ oven dry weight after and before the acetylation (g), respectively.
Sample boards were made based on required target densities with thicknesses of 10 mm. Urea formaldehyde (UF) was applied as resin (10% based on oven dry weights of the used fibers in the board mats). The test boards were made under a press pressure of 30 bars at temperature of 180 °C within 5 min. The boards were conditioned at room temperature and a relative humidity of 65% for two weeks. The sample boards were cut into required sizes for static bending test according to DIN 98754-1. The internal bonding (IB) of the boards as well as the modulus of rapture (MOR) were determined based on three points bending test.
The fracture surfaces of the boards after IB tests were studied after imaging and also fractured surfaces of the tested boards were studied by a Scanning Electron Microscope (SEM).

## RESULTS AND DISCUSSION

According the results, acetylated fibers achieved weight gains of 5, 9 and 16%. It could be expressed that the internal bonding and the modulus of rupture were significantly affected and reduced by the acetylation (Fig. 1).

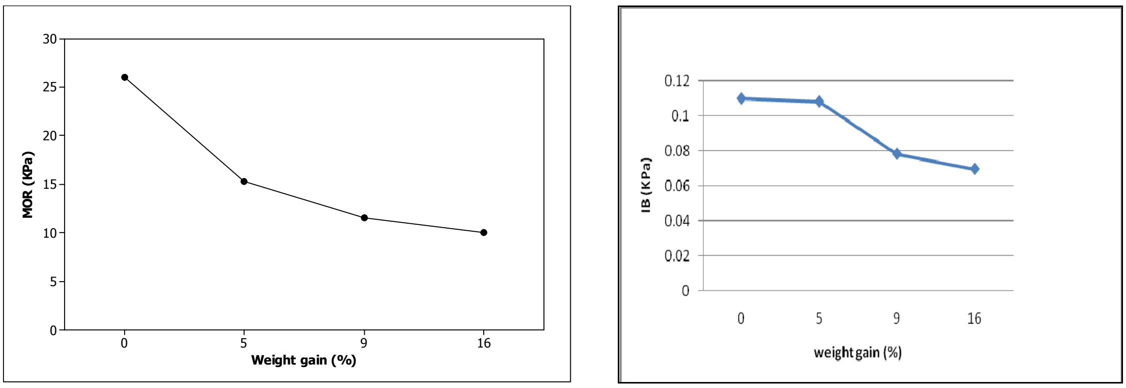
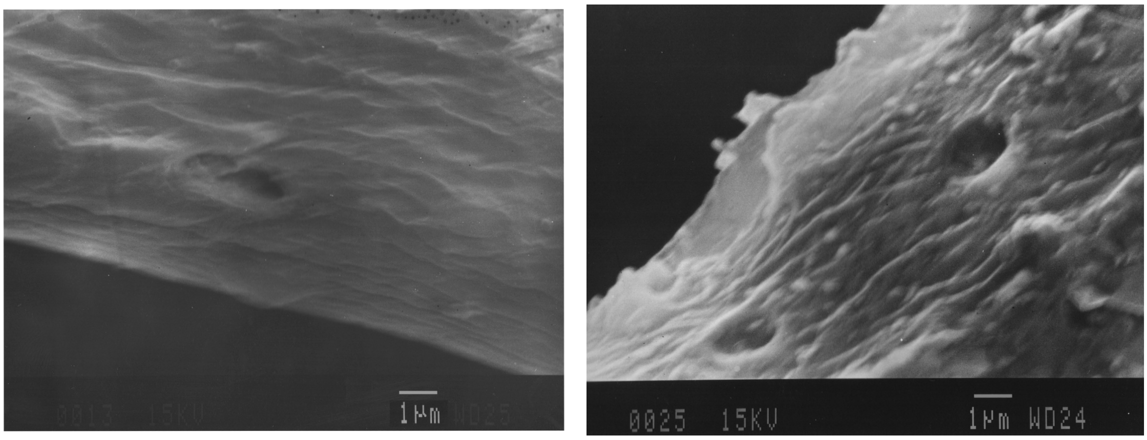



***Fig. 1: Internal bonding and modulus of rupture in acetylated board***

The SEM studies showed that the surfaces of fibers were wrinkled slightly and there was no failure on the surfaces of the treated fibers (Fig. 2). The wrinkled surfaces could be related to the bulking effect of the acetylation. As it has been reported by Sander *et al*. (2003), the acetylation causes bulking of the cell walls.




***WPG 0%*** ***WPG 16%***

***Fig. 2: Scanning electron micrograph of fiber surface***

Study on the images of the IB tested samples showed that the fracture mode was linear in the untreated samples after failure (Fig. 3a), however in the treated samples, the facture mode was revealed as non-linear (Fig. 3b).

***a***

***b***

***Fig. 3: Factures in untreated (a) and acetylated (b) boards after IB test***

According to theories, which were introduced by Popove (1931) and Beer *et al* (1913) about the fracture modes; the fractures in brittle materials are linear and in the supple materials non-liner. Acetylated fibers become rigid and denser according to authors' experiences. In the untreated boards, mostly the fibres and adhesive involve in the board strengths and they both tolerate the mechanical forces, however, in the acetylated boards, the glue lines between adhesive and the fibers are not strong enough due to weaker bonds; therefore, the adhesive mostly involves in the mechanical strengths and tolerates the imposed forces. Due to rigidity, the fibers resist against the mechanical forces; therefore the shear forces play major role to fail the bonds between the adhesive and the fibers. Results of the shear forces are oblique and non-linear fractures in the board profile that were shown in Fig. 3b.

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