Wettability of Hydrothermally Modified MDF

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ABSTRACT

Current research was aimed to study influence of hydrothermal modification on wettability of medium density fibreboard (MDF) by applying contact angle determination of water droplet. Fibres were initially treated in water at 120, 150 and 180 °C at holding time of 0, 30 and 90 min in a stainless steel reactor. Test boards were manufactured with a target density of 0.7 g/cm^3. After conditioning the boards at room temperature, evolution of the distilled water droplets on surfaces of the test boards was recorded in windows movie maker files (WMM format) and images were made in time increments of 5 seconds. Afterwards, the contact angle was determined on the images by applying Image Tools software. Results revealed increase in the contact angle and a decrease in the board wettability as the treatment temperature raises. The holding time showed slight effect at higher temperatures except at 120 °C.

INTRODUCTION

Wood and lignocellulosic materials are modified to enhance their properties. Hydrothermal modification is known as a technique to increase dimensional stability of the wood (Mohebby and Sanaei, 2005), bioresistance (Militz, 2002), colour change (Sundqvist, 2004; Sundqvist *et al*, 2006) and chemical changes (Tjeerdsma *et al*, 1998; Tjeerdsma and Militz, 2005; Boonstra and Tjeerdsma, 2006; Garrote *et al*, 2001). Many research efforts have lead scientists to potential applications of the hydrothermal modification in the wood industries. Most of previous researches were carried out about influence of the heat treatment on the wood properties. However, the researches are tending to study application of the heat treatment on the wood based composites such as OSB (Paul *et al*, 2006) and MDF (Mohebby *et al*, 2008).

The hydrothermal treatment processes are preferred to chemical modification due to the following reasons: **a.** the processes are environmental friendly due to application of no chemicals; **b.** the hemicelluloses are degraded to high yield products with potential industrial applications; **c.** reactions in a mild pH cause less corrosions of devices.

During the hydrothermal treatment, water is used as a heat transient. Chemistry of the wood cell walls is changed due to the hydrothermal treatment (Tjeerdsma and Militz, 2005) and therefore physical and mechanical properties of the wood and its composites are affected. For example, the moisture absorption is decreased and causes increase of hydrophobicity of the wood and wood based composites. Wettability is an indication of their abilities in the moisture absorption. Wood polymers are initially hydrolysed at temperatures of 150-230 °C due to formed hydronium ions from water molecules. Those ions react as catalyst and degrade the cell wall polymers. During the hydrothermal process, ether bonds are cleaved in hemicelluloses and acetyl groups are formed. Acetic acid and formic acid are formed from the acetyl groups after reaction with the

hydronium ions. Those acids act as catalysts and attack the hemicelluloses (Garrote *et al*, 1999).
The heat treatment causes crystallization of cellulose (Yildiz and Gümüşkaya, 2007) affecting the moisture absorption in the wood. Decreased moisture absorption indicates hydrophobicity of the wood and wood based composites. Wettability is an indication of hydrophobic behavior.
The wettability is a potential capability of a liquid to wet surface of a solid material and it relates to molecular interactions between surfaces of both phases (solid and liquid). Distribution of liquid on surfaces of the solid materials is an indication of wetting power of the liquid or wettability of the solid. The wettability is determined by contact angle (Njobuenwu *et al*, 2007). For the first time, Orchon introduced the determination of the contact angle at 1958 (Robert and Schmidt, 1998). It was then used to measure the wettability, glueability and paintability of the wood and wood based materials (Dielhl and Schaumann, 2005; Felix and Gatenholm, 1991).
This property is used to determine the wettability of the hydrothermally modified MDF by monitoring evolution of distilled water with a simple set up.

EXPERIMENTAL

Procedure of the hydrothermal treatment was previously explained by Mohebby *et al* (2008) and samples were cut from those boards and then were used for this research as well. The boards were manufactured from the hydrothermally treated fibres at 120, 150 and 180 °C in water for holding time of 0, 30 and 90 min in a stainless steel reactor. The size of the boards was 350×350×10 mm with a target density of 0.7 g/cm^3 and applied adhesive was urea formaldehyde.

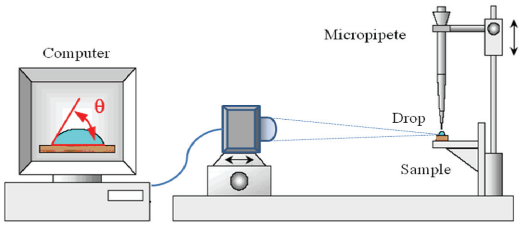

Figure 1: Set up for contact angle determination

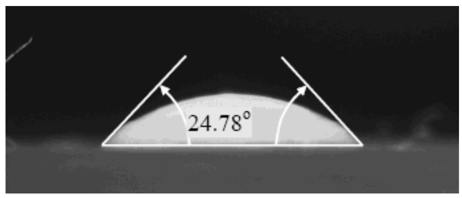

Figure 2: Contact angle determination by goniometry

The contact angle was determined with goniometry method (Diehl and Schaumann, 2005; Felix and Gatenholm, 1991). For this purpose, the test samples were cut from the boards with sizes of 210 mm (length) and 50 mm (width) and conditioned at room temperature and a relative humidity of 50-60 %. Afterwards, droplets of distilled water (25 µl) were dripped gently on the sample surfaces using a micropipette. Immediately evolution of the droplets was recorded by using a digital camera in a computer with Windows Movie Maker (WMM) software (Fig. 1). The recording was continued till when the droplet is disappeared on the board surface. Images of the droplet's evolution were prepared by making photos from recorded WMM files at 5 second intervals since beginning of the evolution till disappearance of the droplets. The contact angle was determined on the photos in both sides of the droplets by using Image Tool software (Fig. 2). On each sample surface two droplets were measured and 10 replicates were considered for every treatment.

RESULTS

Evolution of the contact angle is shown in Fig. 3 for different treatment temperatures and the holding time. It was revealed that the contact angle was increased as the treatment temperature was raised. The contact angle was the smallest in the untreated boards and the droplets were distributed and reached angle zero in short time on the board surface; while the angle was bigger in the treated samples and required longer time to attain the angle zero. Results indicated that the hydrothermal treatment decreased the wettability in the treated boards. At the treatment temperature of 120 °C, the holding time showed significant decreasing effect on the wettability; while it was not significant for higher temperatures.

Comparison between the wettabilities of the treated boards at different evolution time showed that the contact angle was the lowest (73°) at drip time for the untreated boards. However, at the same time the angle was increased in the treated boards as the treatment temperature was raised. At other evolution time, the angle was still lowest in the treated boards and it was increased at higher treatment temperatures. It indicates that the surface tensions on the untreated boards were higher and caused the water droplets to be absorbed immediately under electrical charges of molecules on the board surfaces; while the surface tensions were decreased due to the hydrothermal treatment in the boards.

Determination of the contact angle decrements showed that rate of the decrement was the highest for the untreated boards at the drip time (Fig. 4). It indicates that the droplets were immediately affected by higher surface tension forces at the drip time and they were distributed on the untreated boards. The decrement rate of the contact angle was lower for the treated boards. However, in the treated boards at 120 °C the decrement rate was low at the drip time and it was increased later. Similarly, the contact angle decrement was later begun and it was determined for several times. However, the absorption and distribution of the droplets were low and occurred in fluctuated pattern (stop-start). The fluctuation in droplets distribution on the board surface was similar for the treated samples at treatment temperatures higher than 120 °C.

For the treated samples at 120 °C, the contact angle decrement was decreased as the holding time was extended. Although, the similar pattern was determined for treated samples at higher temperatures, however, the effect of the temperature was more pronounced on the hydrophobicity of the boards.

DISCUSSIONS AND CONCLUSIONS

Results revealed that the contact angle was increased by the treatment temperature. Higher contact angle represents decreased surface tension forces in the boards. The surface tension forces affected the droplets at drip time and later and caused distribution of the droplets on the samples' surfaces.

The surface tensions force is related to the electrical charges of the molecules on sample surface. In the wood and wood based composites, those forces are affected by numbers of the hydroxyl groups in the polysaccharides. Therefore, any decrease of the hydroxyl groups by the hydrothermal treatment affected the wettability of the boards. The hydrothermal treatment caused degradation of the hemicelluloses (Garrote *et al*, 2001) and increase in crystallinity index of the cellulose (Yildiz and Gümüşkaya, 2007). Although, condensation reactions and cross-linkings in the lignin polymer (Tjeerdsma and Militz, 2005) as well as collapses in the wood cell walls due to the hydrothermal treatment (Boonstra *et al*., 2006 a,b) caused reduction in the hydroxyl groups as well as

reduction in cell wall capillarity. Those effects influenced wettability of the treated boards.
It could be concluded from the results that the hydrothermal modification of the fibres decreases wettability of the MDF and increases its hydrophobicity.

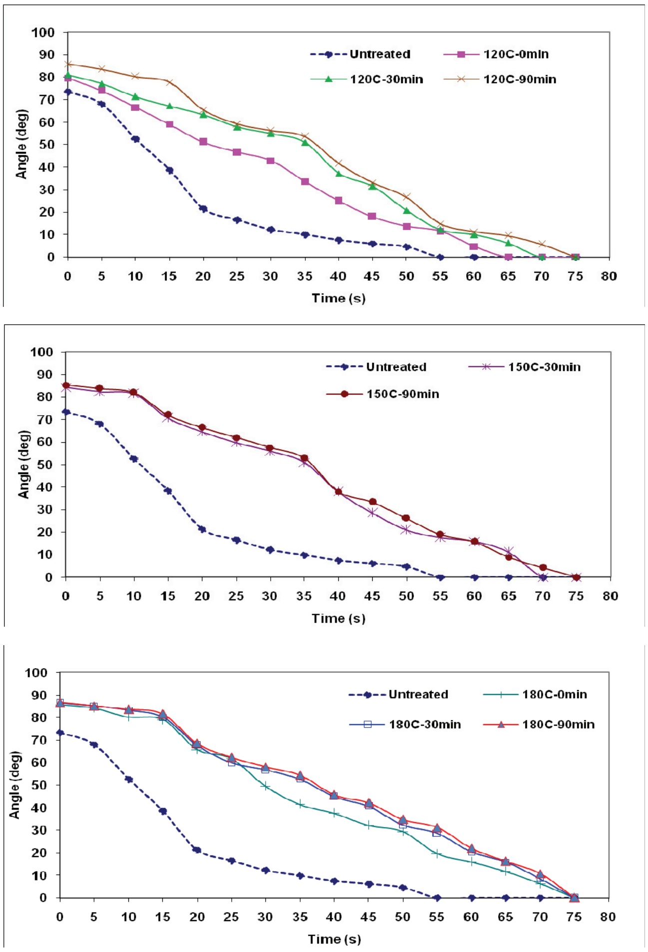

Figure 3: Effect of treatment temperature and holding time on contact angle

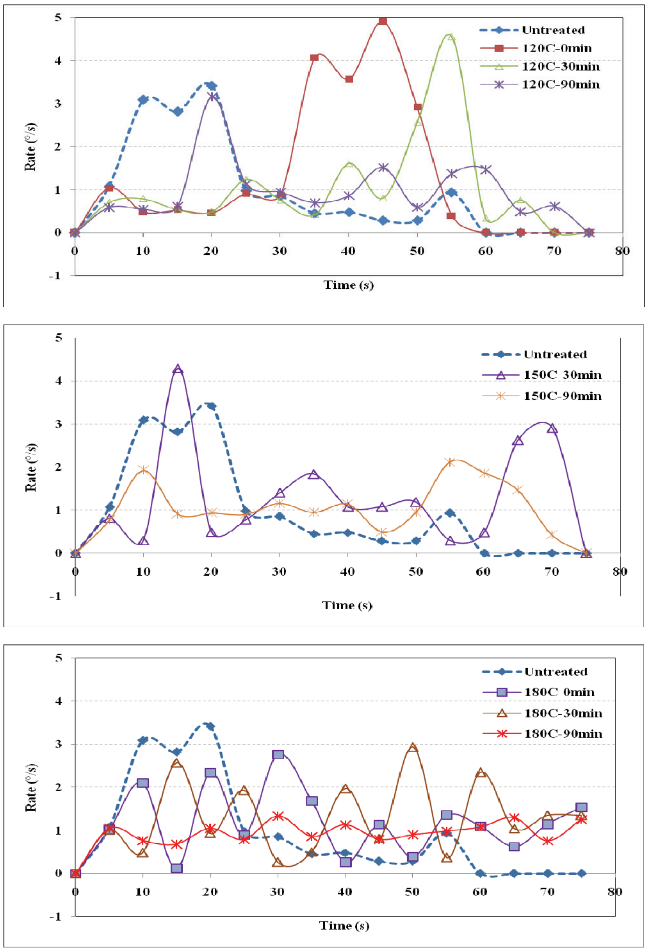

Figure 4: Effect of treatment temperature and holding time on contact angle decrement rate

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