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Evaluation of hardness and surface quality of different wood species as function of heat treatment

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ABSTRACT

The objective of this study was to evaluate the effect of heat treatment on surface roughness and hardness of four wood species, namely black alder (*Alnus glutinosa* L.), red oak (*Quercus falcata* Michx.), Southern pine (*Pinus taeda* L.) and yellow poplar (*Liriodendron tulipifera*). Samples were exposed to heat treatment schedules having two temperature and exposure levels of 120 °C and 190 °C for 3 and 6 h, respectively. Average hardness value of red oak samples exposed to a temperature of 190 °C for 6 h was 41.7% lower than that recorded before the heat treatment. Temperature of 190 °C produced 7.9% lower hardness values for black alder with the increased exposure time from 3 h to 6 h. No significant differences were found between same type of Southern pine and yellow poplar specimens before and after the heat treatment in terms of their hardness values. Among the four species considered in this study red oak having the most porous anatomical structure showed the roughest surface. An improvement in surface quality (R_a) with 7.46% with extending exposure time from 3 h to 6 h at the temperature level of 190 °C was noticed. However all four types of wood species kept in the oven at 190° for 6 h presented smoother surface quality. It was found that increased temperature from 120 °C to 190 °C for both exposure times showed significant differences from the surface quality of nontreated samples at 95% confidence level. The anatomical structure of samples was also observed by scanning electron microscope (SEM) and some damage of the cell wall was determined due to heat treatment. The findings of this study demonstrated that heat treatment resulted in adverse effect on hardness characteristics of the samples. It appears that strength losses can be limited through alternative modified heat treatment techniques. On the other hand, surface quality of the samples from all species was enhanced as a result of heat treatment. Therefore such heat treatment would be considered to improve surface quality of the sample for furniture applications where smooth surfaces are ideal adding potential value on wood material to be used more effectively in furniture manufacturing.

1. Introduction

Wood is one of the most important renewable materials with excellent physical and mechanical properties. However dimensional instability due its hygroscopic behavior is one of the shortcomings of wood and wood products. To enhance such disadvantage of wood many studies have been carried out using different modification processes [1,2]. Heat treatment is the oldest, the least expensive and most eco-friendly modification methods that has been popularly used during the last decade [3,4]. Heat treated wood is generally used for manufacture of parquet and wooden floors, wall and ceiling panels for saunas and kitchens, furniture units, as well as garden fences and window frames for outdoor uses.

The heat treated wood can also be used as substitute of expensive tropical species due to discoloration, improved dimensional stability and biological resistance against fungi and microorganisms [5–8]. Having lower equilibrium moisture content and density along with increased wettability are also important advantages of heat treated wood [9,10]. However adverse influence of heat treatment on mechanical properties of wood is inevitable [11–14]. A typical heat treatment is applied at temperature levels and exposure times ranging from 120 to 250 °C and from 15 min to 24 h, respectively, depending on the process, species, sample size, moisture content and the desired target utilization. Physical and chemical properties of wood under heat treatment change at temperature near 150 °C and it continues with increasing temperature [15,16].

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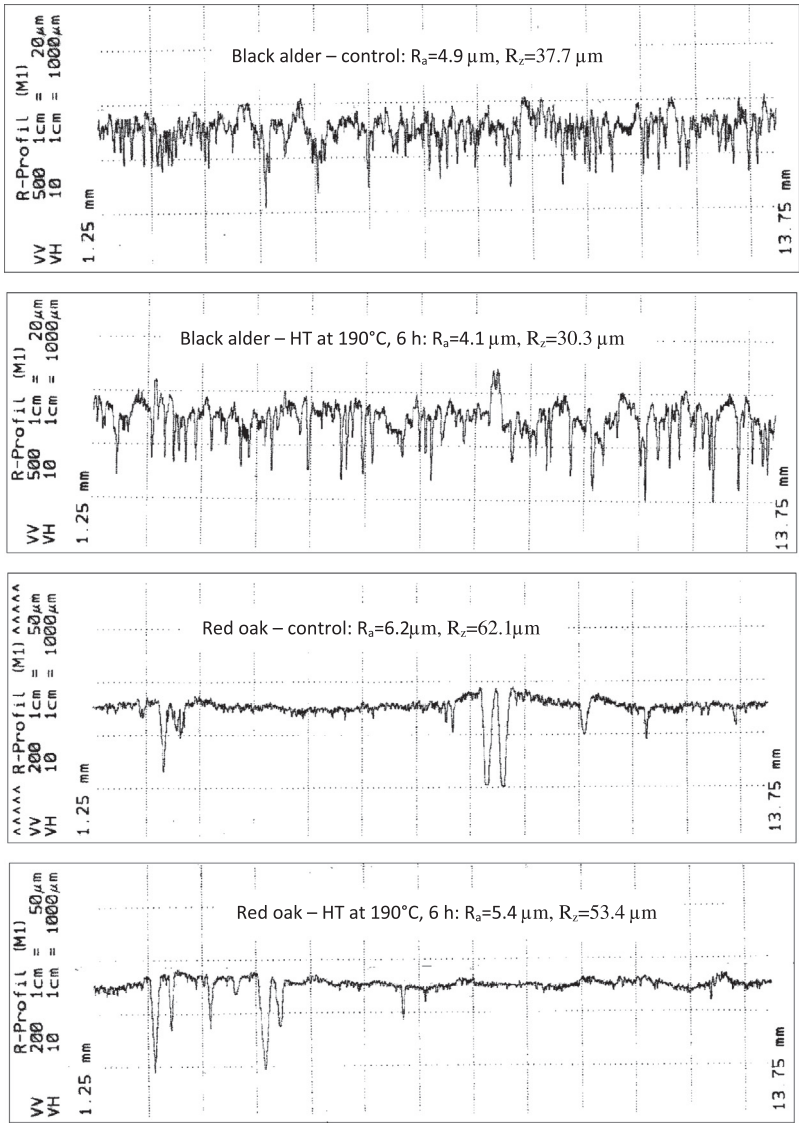

Fig. 1. Typical roughness profiles of the samples.

Micro-structural properties of heat treated wood using scanning electron microscopy (SEM) were also studied in past works [17]. Boonstra pointed out that heat treatment influenced the anatomical structure of wood depending on the wood species and treatment schedule used [5]. Based on visual observation of microphotographs taken from SEM analysis it was found the cross section of heat treated samples of Eastern red cedar presented rather smoother surfaces than that of control samples [18].

Huang et al. [17] determined that slight thinning of middle lamella of the cell wall took place on birch samples as result of heat treatment at temperature levels of 195 °C and 215 °C. Based on the results of various past studies it was also found that structural changes due to heat treatment were not distinct, but it is fact that certain level of plasticization of the cell wall occurred [19–21].

The increase in surface roughness of wood is important for many applications. It is fact that surface roughness of wood can be affected by various factors such as annual ring width, differences between juvenile and mature wood, density, variation between early and late wood and specific cell structures. Redbud maple and hazelnut wood specimens subjected to heat treatment at a temperature of 180 °C for 10 h presented decreased values of surface roughness [15,20]. The average surface roughness (R_a) of red-bud maple decreased up to 15.06%. It also was reported that all mechanical properties including modulus of elasticity (MOE), modulus of rupture (MOR), Janka hardness and compression strength parallel to grain of the specimens decreased with increasing temperature and exposure time [15]. Red bud maple presented 50% reduction in the hardness values when they are exposed at 180 °C for 6 h [15].

The surface quality of mindi, mahogany, red oak and Southern pine wood specimens was significantly enhanced by exposing them to heat at temperature levels of 130 °C and 200 °C for 2 and 8 h [22]. All specimens had smoother surfaces when being subjected to a temperature of 130 °C for 8 h and average roughness values of the samples exposed to 200 °C for 8 h had lower values about 17.8% than the control samples. The overall hardness of all wood species in the same study was influenced by the heat treatment applied. In another study the surface roughness of heat treated Eastern red cedar specimens at three temperature levels of 120, 160 and 190 °C for time spans of 2 and 8 h generally improved but no significant differences were found between surface quality of the specimens exposed to 120 °C compared to those of control samples [18]. Average roughness values were found decreased by 1.87–5.61% versus control which was not significant in the case