Physical and Mechanical Properties of Thermally Modified Aspen Wood

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ABSTRACT

Thermally modified wood is defined as wood heated between 160 and 245 ^{o}C within a controlled oxygen reduced atmosphere. This treatment results in properties different from those of regular wood. The colour of thermally modified wood is also modified. Industrial production of thermally modified wood has been performed at a small scale in Eastern Canada. However, interest for thermally modified wood products is growing. Eastern Canadian wood species selected for thermal modification have been jack pine for outside use like siding and decking and hardwoods such as hard maple, yellow birch, white birch, ash and red oak for inside use like flooring and moldings. However, general interest for trembling aspen (*Populus tremuloides* Michx.) wood is growing since this specie stays available on the market at a good price. Since 2005, Forintek and LTE research laboratories have conducted studies on the development of new products based on thermally modified wood. The general objective of the present study is to determine properties of thermally modified aspen vs. natural kiln dried wood. A 1m^3 capacity TekmaHeat unit based on the Finnish ThermoWood process was used for treatments at three temperature levels including Thermo-S (185 ^{o}C) and Thermo-D (200 ^{o}C) treatment classes, established by the Finnish ThermoWood Association, and 215 ^{o}C. Assessed wood properties were dimensional stability, wear resistance, impact and static bending (MOE and MOR), hardness and resistance to fungal decay. Properties were evaluated following ASTM, ISO and EN standards. Wood colour was also measured after treatment at each temperature level using a colorimeter. Resistance to fungal decay of aspen wood thermally modified at 215 ^{o}C is improved compared with unmodified wood. Thermally modified aspen wood exhibits a significant improvement of its dimensional stability, tangential shrinkage and swelling being reduced by closely 50% at 215 ^{o}C. Thermal modification results in a lower MOR, impact and abrasion resistances. At 215 ^{o}C, MOR value of modified aspen wood is reduced by 13%, resistance to impact by 43% and resistance to abrasion in a ratio of 2.6/1 compared with unmodified wood. The MOE and Janka hardness of thermally modified aspen wood are not significantly affected by the treatment process. Finally, the results highlighted the effect of temperature treatment on the wood properties, including colour.

INTRODUCTION

The general objective of the present study is to determine properties of thermally modified wood vs. natural kiln dried wood. Tests were performed on aspen thermally modified at 185 ^{o}C (Thermo-S), 200 ^{o}C (Thermo-D) and 215 ^{o}C using the Finnish ThermoWood process. Assessed wood properties were wear resistance, dimensional stability, Janka hardness, resistance to fungal decay, impact and static bending (MOE and MOR). Wood colour was also measured.

EXPERIMENTAL

Material used for high-temperature treatments were kiln dried trembling aspen (*Populus tremuloides* Michx.) lumber 25 mm-thick. After treatments, wood was conditioned at 20 °C and 40% RH for two weeks before preparing the required wood samples for each test.

Resistance to abrasion was determined by using a taber abraser with a H-22 abrasive wheel type based on ASTM D 4060 Standard test method for abrasion resistance of organic coatings by the taber abraser. Mass loss of 10 cm x 10 cm x 2 cm-thick specimens was measured after each 100 cycles of abrasive wheel, up to 500 cycles. Dimensional stability was measured in accordance with ISO 4859 Wood–Determination of radial and tangential swelling and ISO 4469 Wood–Determination of radial and tangential shrinkage. Resistance of wood to fungal decay was determined following the EN350 and EN113-1997 Standard test methods of accelerated laboratory test of natural decay resistance of woods. Fungi used in these tests were the brown-rot *Gloeophyllum trabeum* and the white-rots *Coriolus versicolor* and *Serpula lacrymans*. Results are presented as mass-loss percentages after an incubation of 16 weeks. Impact resistance and Janka hardness were evaluated based on ASTM D 143 Standard methods of testing small clear specimens of timber. Impact bending tests were performed on 50 mm x 50 mm x 760 mm specimens. An impact machine with a 22.5-kg hammer was used with a 12.7-mm increasing drop until complete failure or 150-mm deflection of the specimens occurred. Janka hardness was measured by recording the load at which a 11.3 mm in diameter ball penetrates to one half its diameter on surface of 50 mm x 50 mm x 150 mm specimens. Finally, static bending tests based on ASTM D-143 were performed on 25 mm x 25 mm x 410 mm specimens in order to determine MOE and MOR.

RESULTS AND DISCUSSION

Mass loss of unmodified and thermally modified wood samples of aspen at 185, 200 and 215 °C after 500 cycles of the abrasive wheel are shown in Figure 1. Results show that resistance to abrasion of wood is reduced following thermal modification. Also, the resistance to abrasion of thermally modified wood decreases with increment of the treatment temperature.

Figure 2 illustrates tangential shrinkage values for unmodified test specimens and specimens modified at 185, 200 and 215 °C. Maximum shrinkage values were calculated by taking into account the initial dimensions of the test specimens (20 mm cubes) following equilibrium achieved by immersion in water as well as the final dimensions after drying at 103 °C to an oven-dry state. Shrinkage values at a 12% MC were calculated by taking into account the initial dimensions of the test specimens following the equilibrium achieved by immersion in water as well as the final dimensions after conditioning in an environment at 20 °C and 65% RH. Results show that tangential shrinkage of thermally modified wood at 200 and 215 °C decreases with increment of the treatment temperature. However, tangential shrinkage of modified aspen wood at 185 °C is similar to unmodified wood.

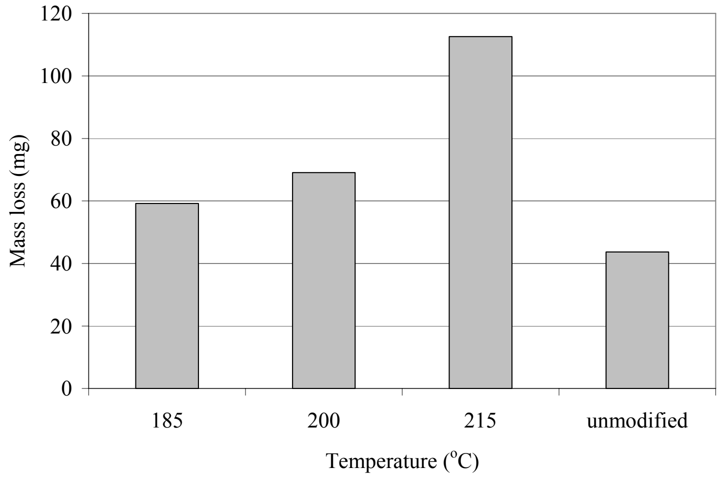

Figure 1: Resistance to abrasion of unmodified and thermally modified aspen at 185, 200 and 215 °C

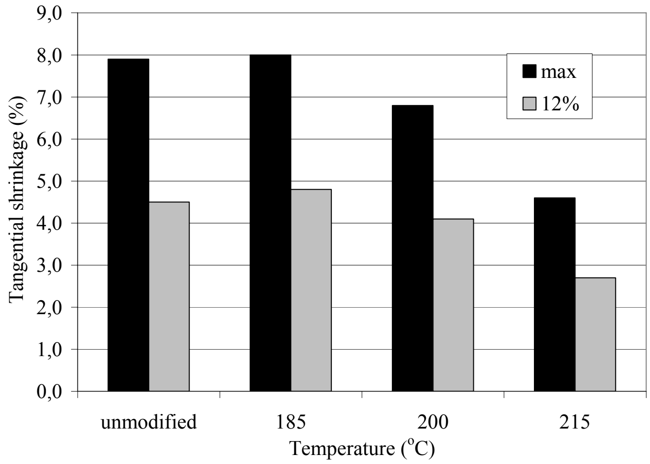

Figure 2: Tangential shrinkage values of unmodified and thermally modified aspen

Figure 3 shows the impact bending test results as the average height of a 22.5 kg hammer drop resulting in a complete failure or 150 mm deflection of the unmodified and thermally modified aspen samples. Resistance to impact bending of thermally modified wood is lower than unmodified wood. Resistance decreases with treatment temperature increase.

From Figure 4, resistance to fungal decay of aspen wood thermally modified at 215°C is improved compared with unmodified wood. Unmodified aspen was mostly affected by brown-rot *Gloeophyllum trabeum* and white-rot *Coriolus versicolor*.

MOE and Janka hardness values for unmodified and thermally modified aspen wood at 185, 200 and 215 °C show that these properties are not adversely affected by the thermal modification process. However, results show a reduction of the MOR of modified wood at 200 and 215 °C compared to unmodified wood of 9.5% and 13.2% respectively. MOR of modified aspen wood at 185 °C is not affected. Finally, the darkening of thermally modified aspen wood can be quantified by the L* (lightness) property measured by a CIE L*A*B spectrometer : L* = 85.6 for unmodified wood, 61.6 for modified wood at 185 °C, 54.7 at 200 °C and 45.9 at 215 °C.

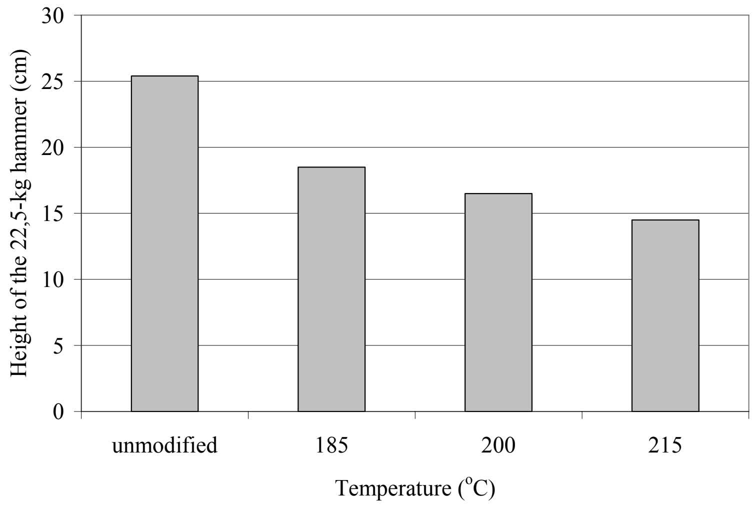

Figure 3: Impact resistance of unmodified and thermally modified aspen

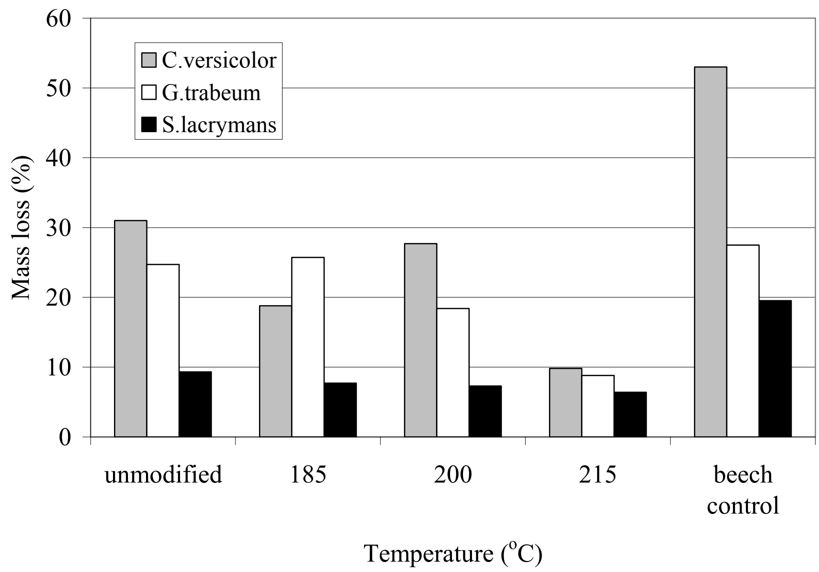

Figure 4: Resistance to fungal decay of unmodified and thermally modified aspen

CONCLUSIONS

Tests results on trembling aspen show an improvement of dimensional stability and resistance to fungal decay after thermal treatments. However, resistance to abrasion, impact bending and MOR are reduced. Properties are generally related to the temperature used for treatments. Finally, results show that MOE and Janka hardness are not affected by treatments.