Study of the wettability and color modification of torrefied wood

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Introduction

Using the Wilhelmy method, to characterize the wettability, which seems to us to be the most suitable, unlike the very used method of the sessile drop; we observe a strong evolution of the advancing contact angle. There is also a strong correlation with the thermal transformation parameters, here the temperature. The evolution is almost linear. The receding contact angle remains constant and equal to zero. The hydrophilic wood becomes hydrophobic after heat treatment. More the wood is treated, more the wood becomes hydrophobic. Obtaining an advancing contact angle = 90° , completely prevents the sorption of water in the wood by capillarity. The wood is protected from liquid water and thus preserved from certain degradation agents. This point is interesting, but deserves to be confirmed over time, depending on the use that is made. This will be the subject of the overall study.

Material and methods

Wood heat treatment

Hardwood: Beech (Fagus Sylvatica)

Softwood : Fir (Abies Alba).

Size: 140mm*60mm*20mm (L*R*T).

Temperature:

120, 140, 160, 180, 190, 200, 210, 220, 230, 240, 250, 275, 300℃.

Heating rate: 2°C/min

Residence time: 120 min

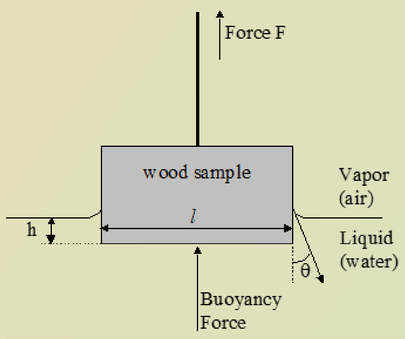
Flow rate of N2: 20 mL/min

Treatment process is realized as following drying of the samples for 48h at 103℃, still mass stabilization, then we measured the weight (M1). After the heat treatment the weight is measured (M2), and the mass loss (ML) calculated:

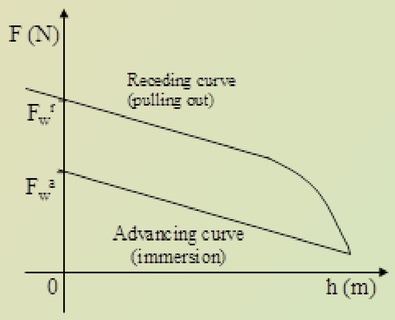
$$ML = (M1-M2)/M1 \qquad \text{Equation 1}$$

Wettability of wood

The advancing contact angles of beech and fir heat-treated at different temperatures were tested by the Wilhelmy method with Krüss machine. We intercepted small samples along the grain from the large specimens (140mm*60mm*20mm) before and after heat treatment for testing, and the specimens heat-treated at each temperature were tested 10 times. The length of the test is 24mm (consistent with the direction of L), the width is 1mm (consistent with the direction of R), the immersion depth is 10mm (consistent with the direction of T), and the immersion speed is 5mm/min. The final contact angle (advancing and receding) values is the average of 10 valid tests.



This figure is a schematic diagram of the Wilhelmy method. Immersing a sample plate (width l) of wood into a probe liquid (water) along an immersion depth (h) and pulling it out allows the calculation of advancing and receding contact angles.



This figure shows the force recorded by tensiometer as a function of immersion depth (h). The wetting forces (F, Fwr; Fwa) applied on the plate and the immersion depth is measured during the test cycle. For the value of the forces the dynamic contact angles can be calculated according to equation:

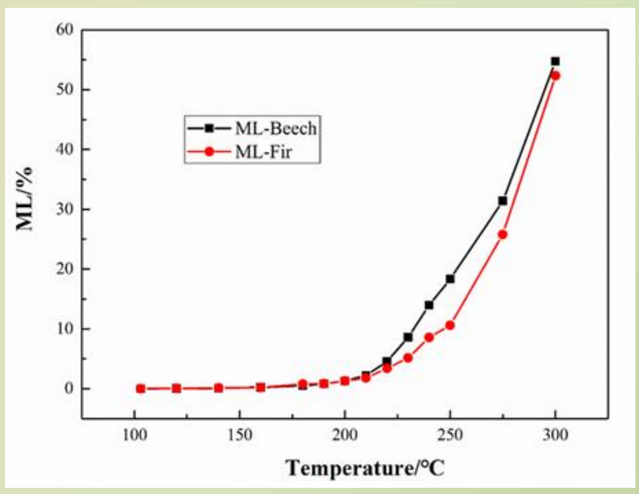
$$Fw = \cos\theta\ \gamma\ P \qquad \text{Equation 2}$$

Where γ is the liquid surface tension and P is the sample perimeter.

Color of wood

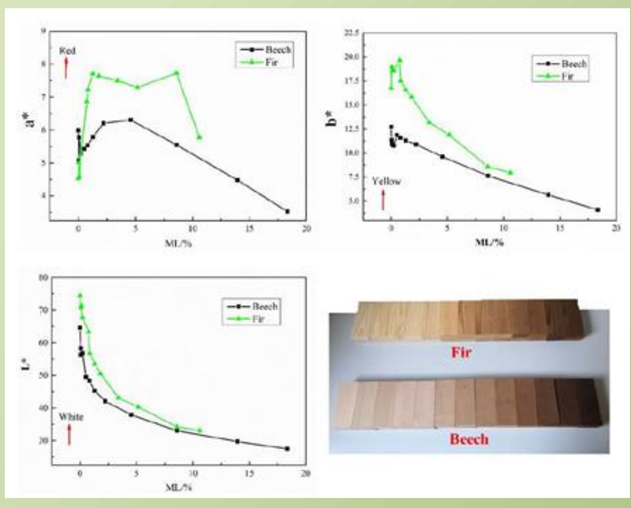
Color change of the heat-treated samples was measured by a Chroma Meter CR-410 spectrophotometer according to the CIELab system using three replicates. Based on the L*, a*, b* color coordinate system.

Results & Discussion



Mass loss

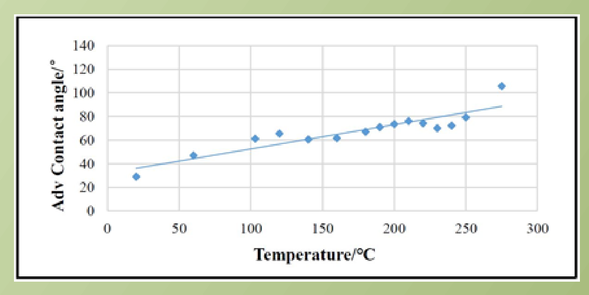
This is a graph of the mass loss trend of beech and fir at different temperatures. As the heat treatment temperature increases, the mass loss of the two types of wood shows an upward trend. Between 100-210°C, the mass loss does not change significantly. Between 210-300°C, the value of mass loss rises sharply. Compared to beech, the mass loss of fir is slightly lower, because the thermosensibility of the hemicelluloses of the hardwood is superior than the softwood.

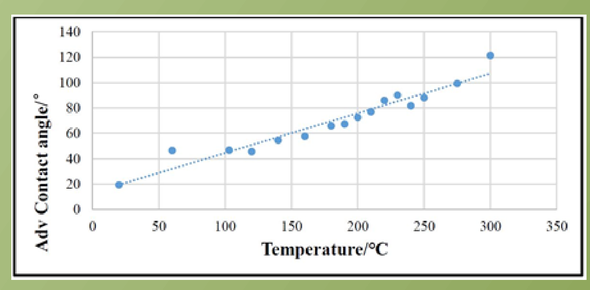


Wood color

This figure shows the color changes of beech and fir specimens under different mass loss. It can be seen from the figure that as the heat treatment temperature continues to increase, the color of the beech and fir specimens will become darker and darker, beech is obviously darker than fir. The color of these two woods before heat treatment is white or yellow. As the heat treatment temperature increases, the degree of white or yellow becomes lower and lower. This change is more obvious in beech than fir.

Wettability





These two graphs are the advancing contact angles of beech and fir heat-treated at different temperatures, tested by the Wilhelmy method. All the measurement of the receding contact angle are equal to zero, that means that before and after the treatment the wood cannot be dewetted by the water. It can be seen from the figure that the advancing contact angles of beech and fir both show a trend of increasing first, then flattening, and finally increasing.

Conclusions

(1) The wood losses its mass as the temperature increases. The evolution is stronger for the beech than for the fir.

(2) The hydrophilic wood becomes hydrophobic after heat treatment. The higher treatment temperature, the more hydrophobic will become.

(3) The wood is protected from liquid water and thus preserved from certain degradation agents.