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Investigation of microscopic properties of some industrial wood species as a result of laser cutting

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Abstract – In this study, the changes in microscopic structures of cellular anatomical structures of some wood species that are frequently used in industrial production as a result of CNC laser processing were investigated. For this purpose, laser cutting was performed on solid wood materials, using a CNC laser machine with a 130-watt carbon dioxide gas glass tube, using 70% watts, at a speed of 15mm/s parallel to and perpendicular to the fibers. The behavior of the cellular anatomical structures of different types of wood solid materials against laser processing was compared.

Keywords – Laser Cutting, Cellular Structure, Woodworking, Anatomical Features, CNC

I. Introduction

Knowing the machinability properties of any material is important for making the best use of it. When it comes to wood material, it becomes even more important to know its characteristic features. Because wood material is more complex and anisotropic than other main engineering materials [1]. On the other hand, since laser processing parameters are a versatile process, it is essential to characterize the wood mechanism in-depth and it is essential to discover the appropriate processing parameter combination to achieve higher efficiency [2]. Since laser cutting means breaking the bond between the fibers by burning, the fiber structure of the solid material should be examined in accordance with the purpose of processing.

Wood is made up of many small units called cells. In a woody cell, there is a cell wall on the outside, very small openings (gates) on the wall that allow the flow of feed water from one cell to another cell, and a cell cavity (lumen) in the middle. Cells come together in various ways to form the wood mass [3].

In this study, using three coniferous and three trees, the effects of laser cutting on the anatomical structure between each tree species were investigated by making comparisons at the microscopic level.

II. Materials and Method

In the study, 3 types of trees, which are widely consumed in industrial production, were used. The densities of wood species in the air-dried state at 12% humidity were measured as 655 kg/m³ in beech, 559 kg/m³ in walnut and 401 kg/m³ in poplar. A CNC laser processing machine with a 130 watt power output, carbon dioxide gas, water cooled, 1.5 mm nozzle diameter and 10.6 µm wavelength used in the study was used.

For the scanning electron microscope (SEM) measurement of wooden solid materials, the test samples were prepared in the form of cubes of 25*25*6 mm size. The laser cutting process was performed at a speed of 15 mm/s with 70% watt power on the perpendicular and parallel surfaces of the 25*6 mm² cross-section fibers. The preparation phase of the test sample is shown in Figure 1 below. SEM images were examined at 2000X operating parameters by cutting four samples from each tree species. SEM images of the samples were obtained using a ZEISS microscope at 0-30 kV acceleration voltage.

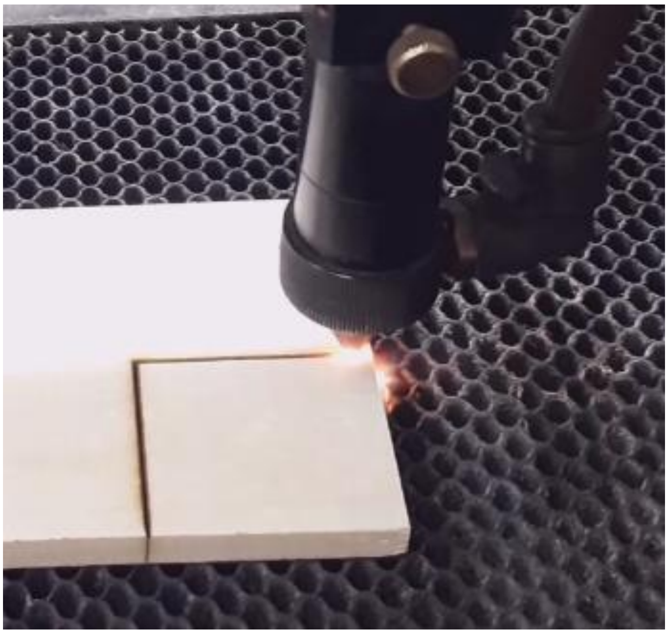

Figure 1. Preparation stage of the test sample

III. RESULTS

A. Cut parallel to the fibers

In Figure 2 below, laser cutting SEM (2000X) images in parallel to the fibers of walnut solid material are given. It is seen that the longitudinal fibers extend in the longitudinal direction in the walnut wood, which has been cut with laser in the longitudinal direction. In addition, carbon melts are seen around the lumen spaces in the transverse direction of the sapphire cells in clusters and their walls are elliptical.

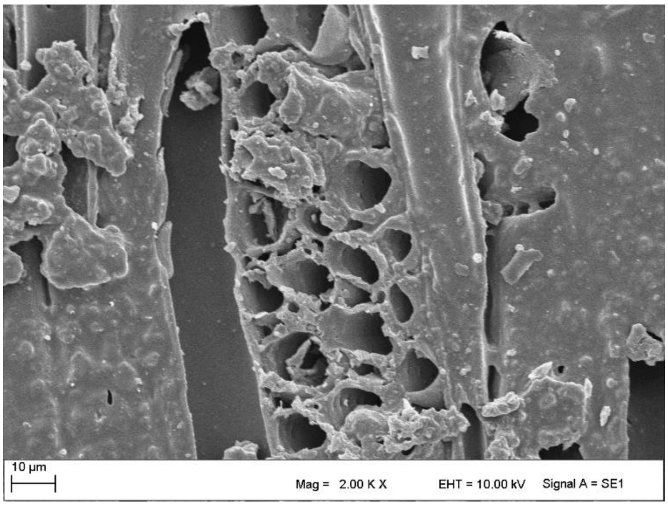

Figure 2. Laser cutting of walnut wood parallel to the fibers

In Figure 3 below, laser cutting SEM (2000X) images are given in parallel to the fibers of the solid beech material. In the beech wood, which is cut longitudinally with laser, the lumens of the fibers extending in the longitudinal direction form channels; Its walls, on the other hand, appear to extend in line stripes. In addition, lumen spaces and walls are seen in the transverse direction of autoray cells in clusters.

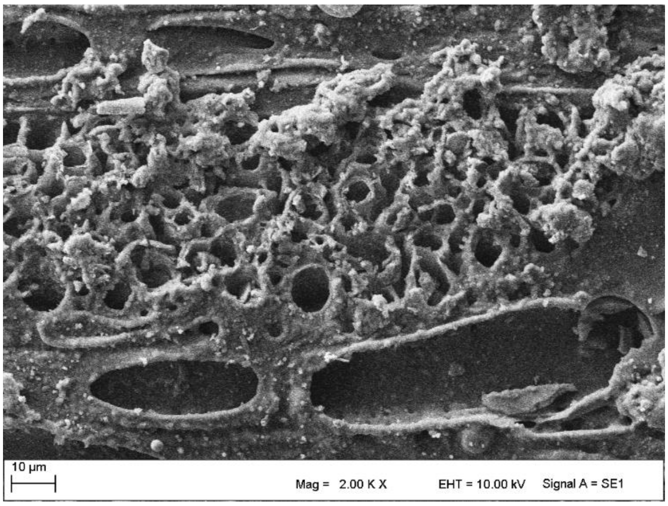

Figure 3. Laser cutting of beech wood parallel to the fibers

In Figure 4 below, laser cutting SEM (2000X) images of the poplar solid material in the direction parallel to the fibers are given. It is seen that the lumens of the trachea extending in the longitudinal direction in the longitudinal direction of the laser cut poplar tree are seen as wide and smooth-walled channels, and the fiber lumens extend as thin channel strips between the tracheas. The fiber walls appear as thin line bands. A break in the fiber wall is observed. It is evaluated that the laser beam coming with air pressure in laser cutting causes micro-fractures or cracks in the wall in a cell structure with wide lumen and weak wall as a result of the heat and pressure applied to the gases in the lumen cavity. Because, due to the change of the chemical functional group on the surface during laser irradiation in poplar wood, the color changes that occur during wood heat treatment tend to decrease with the increase in absorbance (carbonyl stretch of unconjugated ß-ketone and conjugated acid / esters), laser power, and this decrease is probably due to lignin condensation. It has been reported that it results from hemicellulose deacetylation as well as reactions [6].

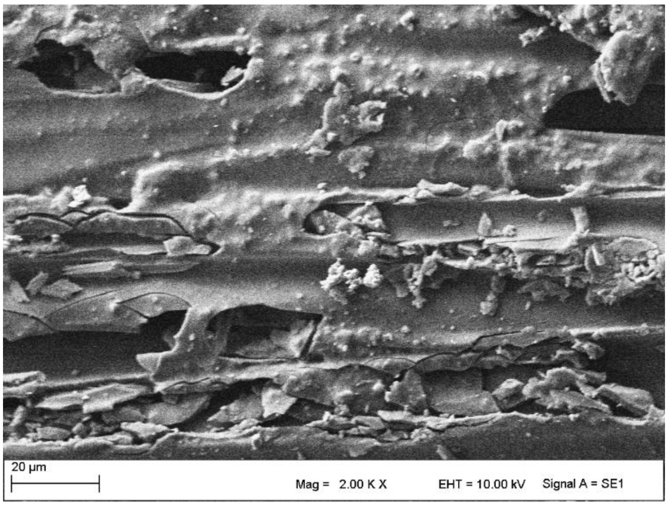

Figure 4. Laser cutting of poplar wood parallel to the fibers

B. Cut perpendicular to the fibers

In Figure 5 below, the laser cutting process and saw cutting SEM (2000X) images perpendicular to the fibers of the walnut solid material are given. The walnut wood was cut with a transverse laser, and it is seen that carbon melts are formed on the fiber walls, partially filling some of the lumen spaces, with the reaction caused by the combustion as a result of the laser cutting process.

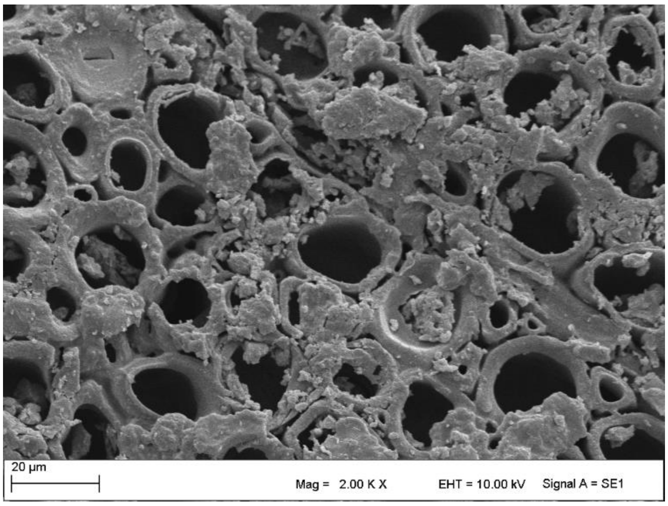

Figure 5. Laser cutting of walnut wood perpendicular to the fibers

In Figure 6 below, laser cutting SEM (2000X) images perpendicular to the fibers of beech solid material are given. Lumens and walls of trachea and fibers extending in the longitudinal direction in beech wood cut in the transverse direction by laser can be seen with a very clear and smooth surface. Beech wood was cut with a laser in the transverse direction, it is seen that carbon melts are formed on the fiber walls with the reaction caused by the burning as a result of laser cutting, and these melts completely close the trachea spaces. It is seen that this carbonization is more than walnut and poplar trees. This may be due to the high density of the beech tree. Because more energy is consumed in trees with high density, it has been explained that laser cutting performance is poor [4]. In addition, this may be due to the chemical structure of the beech. Because the polysaccharide structures in beech change significantly depending on the increasing radiation dose, decarboxylation and degradation of hemicelluloses (mainly deacetylation) reactions are observed, bond cleavage occurs especially in ß-aryl-alkyl ether bonds in lignin, and the degraded particles of woody polymers react together, triggering subsequent condensation reactions. In short, according to FTIR (Fourier transform infrared spectroscopy) data, it was stated that the laser beam dose values had a significant effect on the changes in the main wood components [5].

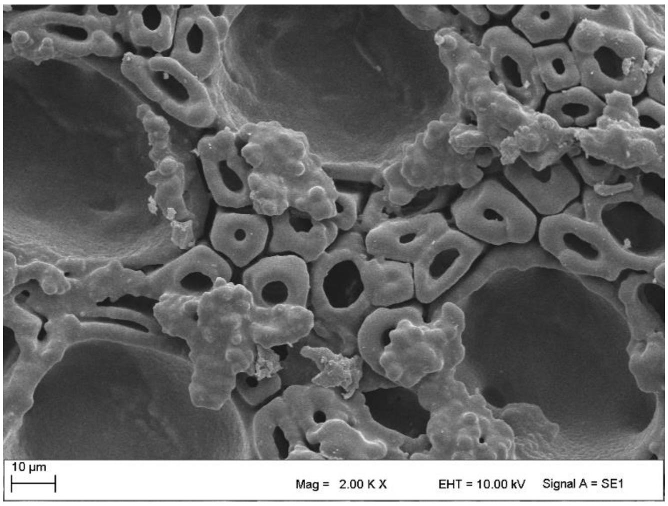

Figure 6. Laser cutting of beech wood perpendicular to the fibers

In Figure 7 below, laser cutting SEM (2000X) images perpendicular to the fibers of the poplar solid material are given. The lumens and walls of the fibers extending in the longitudinal direction in the poplar tree cut with laser in the transverse direction are seen as very clear and smooth surfaced. Poplar wood is cut with a transverse laser, it is seen that carbon melts are formed on the fiber walls with the reaction caused by the burning as a result of laser cutting, but these melts are not as much as in the beech massif due to the thinner wall thickness. It is also seen that the lumen spaces are not filled like the walnut massif. The reason for this is considered to be due to the thin cell walls of the poplar wood species compared to beech and walnut, and the larger trachea and lumen diameters.

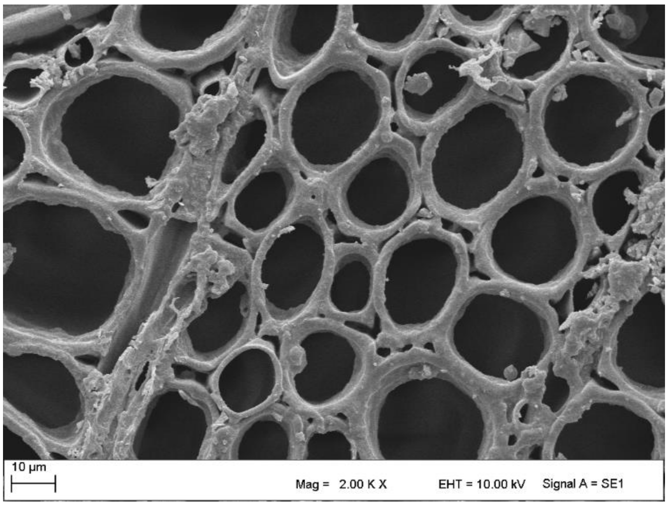

Figure 7. Laser cutting of poplar wood perpendicular to the fibers

IV. CONCLUSION

In this study, the microscopic changes of cellular anatomical structures of some biomaterials frequently used in industrial production as a result of CNC laser processing were investigated. As a result, it has been determined that the laser cutting process creates different surfaces at the microscopic level according to the cell wall, luminal cavity fiber structure and chemical components of solid wood materials.

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