NANOINDENTATION CHARACTERIZATION OF MICROWAVE-PYROLYSIS BIOCHAR

Muhammad Afzal, Bioenergy and Bioproducts Research Lab, University of New Brunswick, Canada
mafzal@unb.ca
Chase Wallace, Department of Mechanical Engineering, University of New Brunswick, Canada
Gobinda Saha, Nanocomposites and Mechanics Lab, University of New Brunswick, Canada

Key Words: Microwave pyrolysis, Biochar, Nanoindentation, Biocomposite materials,

This study investigates the nanoindentation hardness and Young's modulus of microwave pyrolysis biochar developed from hemp and softwood feedstocks. Recent studies have produced encouraging results on the potential for biochar as a reinforcing filler in composite materials, owing to the high porosity and hardness of the carbonous material. In order to further the understanding of the effect of biochar as an additive, and to develop predictive models for the composites, mechanical properties of the chars are needed.

The biochar was synthesized from both hemp and softwood feedstocks, in-house through a microwave-pyrolysis process at 2700 watts, for one hour, with heating rates reaching 50 °C/min and residence temperatures of up to 660°C. Proximate and ultimate analysis were performed as well as physiosorption analysis in order to relate the nanoindentation results to the biochar characteristics. Proximate analysis indicated larger fixed carbon content of softwood (71 wt%), and hemp (72 wt%) with inverse trend for volatile matter. Biochar samples of both softwood and hemp showed an H:C ratio of <1.2 showing a graphite like structure in the biochar. The elemental composition was similar due to the lignocellulosic nature of both biomasses. Porosity results favored hemp biochar which had 12.18 m^2/g BET surface area and 2.58 m^2/g micropore area, compared to 9.96 m^2/g and 1.63 m^2/g BET surface area and micropore area of softwood.

Prior to nanoindentation, biochar samples from each feedstock were cold-mounted, then polished with decreasing grit sizes from 500 to 1200 microns. The Young's modulus and hardness values of the biochar samples were obtained from an iMicro Nanoindentor using a 1mN load. An average of ten indentations were performed on the mounted biochar samples. Nanoindentation results indicated Young's modulus of 5.98 and 5.64 GPa as well as hardness of 0.26 and 0.51 GPa for hemp and softwood char respectively. Considering the nanoindentation results it was observed that heating rates/residence temperatures of pyrolysis and porosity of the biochar are the main factors in overall hardness and modulus. High pyrolysis temperatures allow the char to carbonize to a hardened glass-like state, while faster heating rates aid in the release of softer pyrolytic tars and residue. Furthermore the higher development of healthy micropores at faster heating rates leads to a stronger porous structure, increasing the Young's modulus.

Overall the findings from this study are important indicators of the factors influencing the potential of biochar as a reinforcing filler in biocomposite materials. Knowing the Young's modulus and hardness of biochar is highly useful in the development of analytical predictive models describing the behavior of biochar reinforced biocomposites under various loading conditions.