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Mining and Metallurgy
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PROCEEDINGS

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Editors:
Ljubiša Balanović
Dejan Tanikić

18-21 October 2023, Bor Lake, Serbia

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PREFACE

On behalf of the Organizing Committee, it is a great honor and pleasure to welcome all esteemed participants of the 54th International October Conference on Mining and Metallurgy (IOC 2023), scheduled to take place at the picturesque Bor Lake, Serbia, from October18th to 21st 2023.

The collaborative efforts of the University of Belgrade, the Technical Faculty in Bor, and the Mining and Metallurgy Institute Bor have meticulously organized this year's IOC. Our focus remains unwavering on showcasing the latest research findings and advancements in geology, mining, metallurgy, materials science, technology, environmental protection, and other engineering disciplines. Our primary objective is to foster a dynamic environment where academics, researchers, and industry professionals can come together to share their knowledge, experiences, and innovative ideas while exploring opportunities for collaborative research endeavors.

Our conference agenda is rich and diverse, encompassing plenary sessions, engaging invited lectures, technical presentations, enlightening oral and poster sessions, informative technical tours, a diverse exhibition, and memorable social gatherings. At the heart of this event lies our strong commitment to sustainable development within the mining and metallurgy sector. We are dedicated to exploring ecologically conscious methodologies, responsible resource extraction practices, and cutting-edge technologies that reduce the industry's environmental impact and enhance the well-being of local communities.

The conference proceedings comprise 129 papers authored by individuals from universities, research institutes, and industries in 22 countries. We are proud to welcome participants from Bosnia and Herzegovina, Bulgaria, Canada, China, Croatia, Germany, Greece, India, Iran, Kazakhstan, Libya, North Macedonia, Montenegro, Morocco, Romania, Russia, Slovakia, South Africa, Spain, Turkey, United States, and, of course, Serbia.

We are excited to host the 8th International Student Conference on Technical Sciences (ISC 2023) as part of IOC 2023. This event offers students from Serbia and the wider region a unique chance to showcase their research and discuss the future of their fields with experts.

We sincerely thank the Ministry of Science, Technological Development, and Innovation of the Republic of Serbia for their generous financial support. In addition, we express our profound gratitude to all our sponsors, exhibitors, and friends of the Conference for their contributions and unwavering support for playing a pivotal role in ensuring the success of IOC 2023.

We would like to express our heartfelt thanks to all authors, committees, reviewers, speakers, and chairpersons for their invaluable contributions in shaping IOC 2023.

We look forward to welcoming you to the 55th International October Conference on Mining and Metallurgy (IOC 2024), which will be held in October 2024.

On behalf of the 54th IOC Organizing Committee,

Prof. dr Ljubiša Balanović

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THE PROCESS OF OBTAINING BIOCHAR AND THE DEVELOPMENT OF THE PRODUCTS THUS OBTAINED

Vladimir Jovanović, Dejan Todorović, Branislav Ivošević, Dragan Radulović, Sonja Milićević, Marija Ercegović, Slavica Mihajlović

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Abstract

Biochar continues to strengthen its presence in many new industries with its new applications, which are full of scientific and business news. A flurry of activity has sprung up around this carbon-based material, produced from biomass, following its use in water treatment, energy production and animal husbandry. In any new industry, process and product development, as well as feasibility studies, are very important for the product to come to market. This is especially true when it comes to biochar. Besides being in its infancy as an industry, biochar itself presents a number of challenges that make various tests necessary. Many properties affect the quality and performance of biochar products (pore size, cation exchange, electro-conductivity...) and will most likely vary depending on the starting material and the method of obtaining. Biochar can be made from a very long list of biomass materials. Although the above creates opportunities for industries that abound with highly adaptable products, it can still make biochar unpredictable, given that each starting material affects the characteristics of the final products differently.

***Keywords**: biochar, biomass, pyrolisis, development, processes.*

1. INTRODUCTION

Wood chips, sawdust, corn stover, sugarcane bagasse, and coconut husks represent just a few of the biomass materials that can be transformed into a biochar product. Similarly, even the same material can vary significantly across different sources, with factors such as moisture content, particle size distribution, bulk density, and more all requiring consideration [1].

Biochar is a solid, carbon-rich material generally obtained from thermochemical conversion of biomass and respective carbonization in oxygen-limited environments and has been proposed as a potential solution to climate change, energy security, degradation of natural resources, food security and catastrophic forest fires worldwide. Biochar production implies a complex chemical reaction process where biomass undergoes decomposition, depolymerization and condensation in anoxic high temperature conditions [2].

Biochar is produced by heating biomass in the total or partial absence of oxygen (Figure 1). Pyrolysis is the most common technology employed to produce biochar, and also occurs in the early stages of the combustion and gasification processes. Besides biochar, bio-oil and gas can be collected from modern pyrolysers. These could be refined to a range of chemicals and/or used as sources of renewable energy if derived from sustainably produced biomass [3].

Figure 1 - Biochar

2. THE PRODUCTS

Biomass: living or once-living material, which is the feedstock (starting material) for making biochar. Nearly all organic materials, such as bark, nutshells, crop residues, and manurescan be used as feedstock in appropriate devices [4].

Charcoal: the solid, carbon-rich residue left when biomass is heated in an environment with limited oxygen. Generally, charcoal is made from wood, and is intended for use as fuel. Charcoal can be further processed to produce “activated carbon”.

Biochar: a charcoal-like material made under suitable conditions from non-contaminated starting material, and crushed into small pieces for mixing in the soil. It is often enhanced with nutrients and microorganisms, intended to improve soil properties and plant growth [5].

Char: a general term for the solid product arising from thermal decomposition (pyrolysis) of any organic material.

Pyrogas (or Pyrolysis gas): The gas and aerosols from pyrolysis or gasification comprising primarily combustible gases CO, H_2 and CH_4 along with CO_2, steam and N_2; also known as wood gas and syngas.

Ash: Inorganic compounds in the biochar. (Also refers to material remaining after combustion, which includes a small percentage of carbon.) [6]

3. THE PROCESSES

Pyrolysis (from Greek roots pyr“fire” and lysis “loosening”) is the thermal decomposition (breakdown under heat), in a limited oxygen environment, of biomass into a carbon-rich solid residue (char), gases, and liquids. [7]

Carbonisation emphasizes the carbon enrichment, as opposed to the “breakdown”, aspect of pyrolysis. “Carbonization” is often used interchangeably with “pyrolysis.”

Conditioning refers to changes in chemical and physical properties of biomass at temperatures of approx. 110-180oC, where biomass starts to soften and chemically-bound water starts to be driven off.

Torrefaction is a chemical process that takes place at a temperature of approx. 180-300oC which produces a more energy dense, stable, sterile feedstock or soil amendment [5].

Activation refers to further enhancement of charcoal via chemical processes and/or higher temperature oxidation to produce activated carbonwith high microporosity and surface area.

Gasification is the conversion of biomass into a gas commonly referred to as “producer gas”, using a limited amount of air or steam. A gas rich in CO, CH4, CO2 and H2 is produced. [6]

3.1 Processing Conditions

In addition to the characteristics of the source material influencing the end product, the processing conditions also have an impact on the characteristics of the end product.

Biochar is produced from biomass through a process called pyrolysis, in which dried biomass is processed in an oxygen-free atmosphere at temperatures between 250 – 430ºC . This is typically carried out in an indirect-fired rotary kiln (Figure 2), or pyrolysis kiln.

A variety of process parameters such as retention time, temperature, and more will all play a role in shaping the characteristics of the end product and in turn, how it performs. [8]

Figure 2 - Drying of various materials in indirect kiln[1]

3.2 Biochar Testing Facilities

As a developing industry, the supply of testing facilities hasn’t quite caught up with the demand. We have definitely seen an influx of inquiries around testing biochar lately, People are coming to develop biochar for use in all sorts of applications and to test each part of the process – agglomeration, drying, and high temp thermal processing. This allows them to zero-in on exactly what’s working and what needs improvement.

3.3 Types of Testing Available

While pyrolysis is a major focus of the process development stage, it is also necessary to test the drying and agglomeration steps. In each scenario, testing helps to define process data and provide the information necessary for scale-up to commercial production capacities. Testing will also help to determine if any sort of pre-treatment (such as grinding or mixing) will be required. [9]

3.4 Drying

Few materials can boast such significant variation in characteristics as biomass. Before biomass can be pyrolyzed in a rotary kiln, it must first be dried. The variation in moisture content, particle size distribution, and more require a biomass drying system to be designed around the unique source at hand to produce the most efficient drying solution. Drying is also necessary as a downstream step to agglomeration.

Drying parameters such as temperatures, retention time, flight design and pattern can all be worked out through testing.

3.5 Pyrolysis

The pyrolysis process also requires testing to work out process variables and design a commercial scale unit.

Testing for pyrolysis is typically carried out first at batch scale, then at pilot scale. Testing around pyrolysis helps to determine the rotary kiln design parameters that will best suit the material at hand to produce the desired results.

3.6 Agglomeration

Biochar leaving the rotary kiln is in the form of a powder. Although biochar can be used in powder form, it is often desirable to agglomerate it, particularly in the case of soil amendments [10]. Some biochars may be difficult to pelletize alone and as such, may be included as part of a blend to assist in enabling successful agglomeration [11].

Soil amendment producers are often looking to combine biochar with other materials such as compost in order to create a specialized product [12].

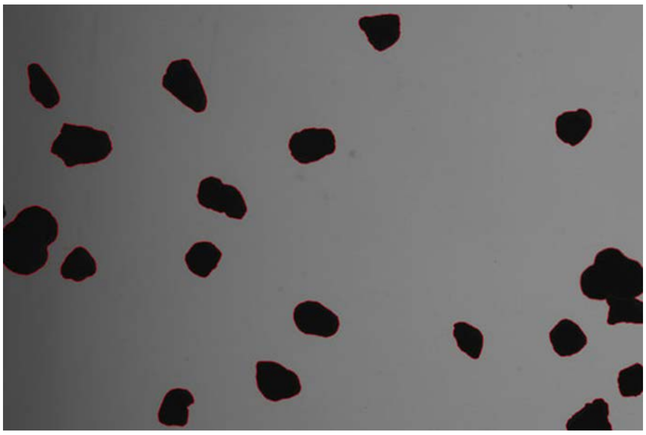

Figure 3 - Particle Analysis

4. PARTICLE ANALYSIS

Throughout biochar testing, it is necessary to analyze particles for a variety of parameters.

A 3D Dynamic Image Analysis tool can provide real-time particle analysis during testing to measure density, thickness, surface roughness, size, shape, and more (Figure 3).

Furthermore, particles can be analyzed to determine attrition, compression, crush strength, green/wet strength, moisture content, and more to ensure particles will perform exactly as desired. [1]

5. AUTOMATION

A variety of data points can be tracked, trended, and even adjusted in real-time to create a seamless and highly intuitive testing experience.

6. CONCLUSION

Various characteristics, including pore size, cation exchange, electrical conductivity, and more will influence the performance of a biochar product and are all likely to differ based on the source material and the processing conditions. Biochar can be created from a nearly endless list of biomass materials.

Testing is a critical part of any new industry, but may be especially important with biochar, due to its significant variability and the challenges it can present. As new applications for biochar are constantly developing, the need for testing facilities is in high demand.

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