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ScienceDirect

Energy Procedia 138 (2017) 319–324

Energy Procedia

www.elsevier.com/locate/procedia

2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies
2017 AEDCEE, 25 - 26 May 2017, Bangkok, Thailand

Modelling Anhydrous Weight Loss of Torrefied Wood Sawdust

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Abstract

Saw mill industries in Malaysia produce a large amount of biomass waste in the form of sawdust, especially from Cengal and Kulim wood species. One of the attractive options to utilize the available biomass is by converting it to an alternative biofuels via torrefaction process. During torrefaction process, biomass is thermally decomposed thus resulted in biomass weight loss which is known as an anhydrous weight loss (AWL). In this study, the kinetic parameters were predicted by two step reactions in series known as Di Blasi – Lanzetta model for both heating and isothermal phases to achieve the desired AWL of torrefied Cengal and Kulim sawdust at temperature of 240°C, 270°C, and 300°C. All kinetic parameters are estimated according to Arrhenius law and fitted to the experimental result. The mass yield results shows that at higher temperature of 300°C, the rate of degradation is higher compared to the lower torrefaction temperature for both Cengal and Kulim woods due to the hemicellulose and cellulose wood constituents. In conclusion, the Di Blasi – Lanzetta model is reliable to predict the AWL of Cengal and Kulim woods in achieving the desired torrefied biomass properties.

Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.

Keywords: Torrefaction; Wood Sawdust; Anhydrous Weight Loss; Parameter Estimation; Two Consecutive Reaction Model;

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Peer-review under responsibility of the scientific committee of the 2017 International Conference on Alternative Energy in Developing Countries and Emerging Economies.
10.1016/j.egypro.2017.10.125

1. Introduction

Renewable energy is a fundamental and growing part of the world ongoing energy transformation. A significant growth of urbanization leads to diminish fossil fuel reserves, serious environmental pollution and high greenhouse gas (GHG) emissions. Hence, the use of renewable energy is the prime choice for enhancing access to affordable, reliable and cleaner sources of modern energy services. According to International Energy Agency (IEA) report in 2016, nearly 60% of the power generated in 2040 is projected from renewable energy [1]. Among the renewable energy and alternative fuels under development, biomass is one of the promising resources to match the requirements of fossil fuels substitution. Malaysia known to have a luxuriant tropical forest and the saw mill industry from forestry sector have a significant contribution to the socio-economy in the country. The waste generated from saw mill industries contribute to one of the sources of biomass in Malaysia. Biomass can be transformed into gas or liquid fuels via variety of methods such as gasification, pyrolysis, anaerobic digestion, fermentation and transesterification [1]. However, biomass is characterized by its high moisture content, low calorific value, hygroscopic nature and large volume or low bulk density, which result in a low conversion efficiency as well as difficulties in its collection, grinding, storage and transportation. For those reasons, biomass needs to be pretreated before it can be converted into high-value-added products [2].

Among the explored biomass upgrading methods, torrefaction is a promising route for solid fuel production. Theoretically, torrefaction is an incomplete pyrolysis processor known as mild pyrolysis with reaction temperature between 200°C to 300°C, and residence time up to 60 minutes under inert condition. This process upgrades the solid fuel quality by reducing the moisture content, increase heating value, improve grindability, and increase carbon content as well as making the torrefied product become more brittle. Therefore, many studies and research on torrefaction process have been conducted in recent years and focused on the property changes of biomass [2-4]. However, less attention has been paid to the kinetic parameters study of biomass torrefaction. The kinetic study of torrefaction process is essential because it representing the kinetic reaction in torrefaction process which can be used to improve process control for continuous torrefaction reactor. Therefore, it is important to study and estimate the kinetic parameters of torrefaction process in order to determine the optimum condition for thermal degradation process in achieving the desired properties of torrefied product. Thermal degradation in torrefaction is described by anhydrous weight loss (AWL) of the biomass.

In the present work, the torrefaction of forestry residues from Cengal and Kulim wood sawdust being torrefied at three different temperatures (240°C, 270°C and 300°C) using thermogravimetric analysis (TGA) in order to determine the residual mass. For the kinetic modelling, Di Blasi-Lanzetta model was used to predict the residual mass of wood sawdust at all temperature. However, previous studies conducted on the torrefaction kinetic studies only considering the isothermal phase of torrefaction [3-4]. Therefore, in this study both heating (non-isothermal) and isothermal phases of torrefaction are taken into account when deriving the kinetic parameters. Based on both heating and isothermal phases, the kinetic parameters for all temperatures are estimated and fitted against the residual mass obtained from TGA and the applicability of these models in predicting residual mass as well as the mass yield were also discussed.

2. Materials and Method

2.1 Materials and thermogravimetric analysis

The samples used for the torrefaction process were Cengal and Kulim sawdust from logging residue. Prior to the thermogravimetric analysis (TGA), the samples were heated from 30°C up to 105°C at 10°C/min and were held for 5 minutes in order to remove all moisture that trapped inside the samples The samples weight were varied from 5 mg to 10 mg and the average sample particle is around 50 µm to 100 µm. A TGA/DSC 1 Mettler Toledo analyser was used in this study to evaluate the mass loss of biomass during the torrefaction process with nitrogen flow of 30ml/min. Cengal and Kulim sawdust were tested at three different temperatures : 240°C, 270°C and 300°C with heating rates of 10°C/min. The samples were heated at the desired temperature and were held for 90 minutes. The data obtained from TGA experiment were used to calculate the AWL for each sample at respective temperature and compared with the model prediction data from simulation work.