ISBN 978-93-5156-328-0
International Conference of Advance Research and Innovation (ICARI-2014)

Theoretical Implementation of Torrefied Biomass as A Fuel in the Gasification Process

Rahul Singh, Supriya Vats *, Neelam Baghel, Pushpendra Singh
Department of Mechanical Engineering, Delhi Technological University, New Delhi, India

Article Info

Article history:
Received 2 January 2014
Received in revised form
10 January 2014
Accepted 20 January 2014
Available online 1 February 2014

Keywords

Biomass,
Gasification,
Torrefaction

Abstract

To meet in the on growing energy demands and to compensating for the emissions caused due to fossil fuels biomass gasification process is employed. Torrefied biomass gasification provides clean energy with fewer emissions as compared to fossil fuels like coal.

In this paper an attempt has been made to study the viability of torrefied biomass as an alternate source of fuel, its scope and limitations in the gasification process. The torrefied biomass has been found out to be a better fuel than the original biomass and quite competent to coal in the gasification process. The paper is a review of the integration of the torrefaction and the gasification process.

1. Introduction

The last century witnessed a tremendous increase in the fossil fuel use. With the tremendous increase in the fossil fuel use the fossil fuel reserves started depleting reaching an alarming state. The increase use of fossil fuels is also causing rise in the emissions caused due to their burning there by increasing the pollution level and causing global warming.

A solution to the abovestated problem is to adopt biomass gasification. Biomass gasification provides syngas with fewer emissions as compared to fossil fuels. A novel approach to biomass gasification is to use torrefied biomass as compared to raw biomass for the syngas production.

2. Gasification

Gasification is a process that converts organic or fossil based carbonaceous materials into carbon monoxide, hydrogen and carbon dioxide. The process of gasification is carried out by reacting coal, biomass or any other carbonaceous based organic substance at high temperature of about 700^0Cin the absence of combustion and very little amount of oxygen or steam. The gasifier is fed with a variety of biomass fuels like charcoal, wood agricultural wastes, wood waste; to give resulting gas mixture called syngas or producer gas.

The gasifiers are of several types like counter current fixed bed (up draft) gasifier, co current fixed bed (down draft) gasifier, fluidized bed reactor, entrained flow gasifier and plasma gasifier.

Corresponding Author,
E-mail address: supriya.vats19@gmail.com

3. Torrefaction Process

The torrefaction process is carried out by reacting the biomass such as wood waste or wood or agricultural biomass at temperature of about 200-300^0C in a torrefaction reactor in the absence of air and under atmospheric pressure.During the process the biomass decomposes giving off various types of volatiles which results in loss of mass and chemical energy to the gas phase. The yield of mass and energy from the original biomass to the torrefied biomass is strongly dependent on torrefaction temperature, reaction time, and biomass type. Typical values are a mass and energy yield of 0.8 and 0.9 respectively (LHVdar). Hence, in torrefaction more mass than energy is lost to the gas phase. This phenomenon results in energy densification (higher LHVdar), on 'as received' basis' the mass and energy yields can be even 0.45 and 0.9 respectively (35% moisture content) [1].

4. Feed Stock Requirement

The torrefied biomass can be obtained from a variety of woody and herbaceous biomass substances [2]. A variety of biomass products can be torrefied to yield torrefied biomass. However the mass and energy yield of the torrefied biomass varies from one substance to another depending upon the original biomass and the operating conditions because of polymeric conditions and reactivity of different substances. The particle size also does not affect the

torrefaction process. Therefore any size of particle can be used in the torrefaction process.

5. Torrefied Biomass

The torrefied biomass attains properties of coal which are very useful in the gasification process. The torrefied biomass looks dark brown in color. Even though the torrefied biomass retains the dimension and shape of the raw material, it has low bulk density.

Grindability- the grindability of the biomass is increased due enhancement of biomass brittleness. This property is useful in gasification and pyrolysis especially in fluidized bed systems.

Hydrophobicity- the torrefied biomass is a hydrophobic, water repelling fuel. Torrefaction improves the water repelling characteristics of biomass through the elimination of hydroxyl groups responsible for hydrogen bonding with water molecules, and the generation of a non-polar, hydrophobic compound [3, 4, 5].

Energy density-the energy density of biomass increases as a result of oxygen loss during torrefaction. This increase can be in the range between 102-120%, depending on reaction conditions [6]. Energy and bulk density of torrefied biomass can be further improved via pelletizing [3].

Combustion properties- Torrefied biomass created a greater heat of combustion due to a higher fixed carbon content. In addition, the ignition time of volatiles and char decreased as aconsequence of torrefaction, which could be an advantage during combustion

6. Torrefied Biomass as A Fuel in Gasification Process

The gasification process is comprised of many stages which can be broadly divided into upstream processing, gasification and downstream processing. The upstream processing comprises of preprocessing of biomass which is reduction in the biomass size, drying and preparation of the gasifying agents. The gasification process involves heating, chemical reaction and catalytic action. The downstream processing of biomass includes gas clean up and reforming and gas utilization. Cleaning of the tar from the syngas and reforming of the syngas forms part of the gas clean up and reforming [3].

Torrefied biomass can be very well utilized in the gasification process because it has already lost its moisture during the heating phase. Also because the grindability of biomass has already increased due to torrefaction it can be very well used in the gasification process.

The torrefied biomass attains properties which can be used in the gasification process. The properties of torrefied biomass have been tested for the gasification process using several types of reactors like air-blown gasification of wood, air-blowngasification of torrefied wood in a circulating fluidized-bed, and oxygen-blown gasificationof torrefied wood in an entrained-flow gasifier.it was found from the study that the overall efficiency of the air-blown gasification of torrefied wood was lower than the gasification of untreated wood.On integration of torrefaction and gasification processes, overall efficiency increases to a level comparable to gasification of raw wood.The gasification of torrefied biomass can be done at elevated pressures, which may be useful for downstream energy production in turbines or for production of chemicals [7].This cannot be achieved with raw biomass due to issues with its feeding in pressurized systems.

It has been found that torrefied biomass is helpful in providing feed in an entrained flow gasifier. Therefore by providing torrefied biomass in an entrained flow gasifier we can get a continuous supply of syngas. As the torrefied biomass is of reduced size than the original biomass, it provides an energy friendly operation due to which its overall efficiency is improved.It thus reduces the operation cost and the possible capacity of the plant increases due to in investment cost [8].

Its also seen that the gasification of torrefied biomass provides a synthetic gas of higher quality. In a study to evaluate the potential of the technique, gasification processes for three different materials including raw bamboo, torrefied bamboo and high volatile bituminous coal in entrained flow gasifier using O_2 as gasification agent were studied numerically and compared. The result showed that the carbon conversion of three fuels was higher than 90%. The coal gasification technique of raw bamboo was low due to its lower calorific value.in case of torrefied biomass the gasification process was highly enhanced. Under optimum conditions with respect to the equivalence ratio the cold efficiency of torrefied biomass was highly improved [9].

7. Conclusion and Future Scope

It has been examined and analyzed from literature review that the torrefied biomass is very much useful in the gasification process. By using torrefied biomass in the biomass gasifier instead of raw biomass the efficiency of the gasifier can be improved effectively.

There is need of detailed analysis of the end products when torrefied biomass is used as fuel for the gasification process. Also great scope also lies in integrating the torrefaction process and the gasification process.

References

[1] Patrick C. A. Bergman, Jacob H. A. Kiel Torrefaction for biomass upgrading, published at 14th European Biomass Conference & Exhibition, Paris, France, 17-21, 2005

[2] Dana Mitchel, Tom Elder Torrefaction? What's that? Fueling the Future: Council on Forest Engineering Annual Meeting 6-9, 2010, Auburn, Alabama

[3] Dorde Medic, Investigation of torrefaction process parameters and characterization of torrefied biomass, 2012, Iowa University

[4] T. C. Acharjee, C. J. Coronella, V. R. Vasquez, Effect of thermal pretreatment on equilibrium moisture content of lignocellulosic biomass. Bioresour. Technol. 2011, 102,4849-4854

[5] N. Kobayashi, N. Okada, A. Hirakawa, T. Sato, J. Kobayashi, S. Hatano, Y. Itaya, S. Mori, Characteristics of solid residues obtained from hot-compressed-water treatment of woody biomass. Ind. Eng. Chem. 2009, 48, 373–379.

[6] D. Ciolkosz, R. Wallace, A review of torrefaction for bioenergy feedstock production. Biofuels, Bioprod. Biorefin. 2011, 5, 317-329

[7] Ajay Kumar, David D. Jones, Milford A. Hanna, Thermochemical Biomass Gasification: A Review of the Current Status of the Technology energies ISSN 1996-1073

[8] P.C.A. Bergman A.R. Boersma J.H.A. Kiel M.J. PrinsK.J. Ptasinski F.J.J.G. JanssenTorrefaction for entrained-flow gasification of biomass

[9] Wei-Hsin Chen, Chih-Jung Chen, Chen-I Hung, Cheng-Hsien Shen, Heng-Wen Hsu Wei-Hsin Chen, Chih-Jung Chen , Chen-I Hung, Cheng-Hsien Shen, Heng-Wen Hsu, A comparison of gasification phenomena among raw biomass, torrefied .biomass and coal in an entrained-flow reactor