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Performance Analysis of Solar Torrefaction Unit Coupled With Double Reflector

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Abstract: *Torrefaction is an emerging thermal pretreatment of biomass, which produces a solid biofuel having superior handling, milling, storage and co-firing properties compared to raw biomass. Torrefaction of biomass, eg: wood or other biomass materials, is a mild form of pyrolysis temperatures typically between 100℃ and 300℃. Torrefaction changes the biomass properties to provide much better fuel quality for combustion and gasification applications. The relatively low process temperature of torrefaction makes the use of solar energy with low cost. In this work wood and tomato peels are used to test the feasibility of solar energy in torrefaction process and also study the efficiency of parabolic trough collector with secondary reflector with the application of water filtration. Here uses lens for torrefaction purpose for improving the time and temperature of torrefaction. The device was fabricated and various locally available wood species and tomato peels were tested. The yield was found to be 21% to 25% with a production time of 7hours. The efficiency of parabolic trough with secondary reflector was found to be about 30%.*

1. Introduction

Nowadays energy demand is increasing from year to year this trend is also supported by environment concerns such as global warming and climate change which have resulted from increased of fossil fuel. Preferably, the world should move towards more renewable energy. Biomass is an important source of renewable energy which can be converted to produce energy by various technologies. It is considered as an environmentally friendly, carbon-neutral fuel. It is an important energy source to create a more sustainable society. Biomass is a primary type of renewable energy which is expected to be an important energy source in the coming years. Biomass is the 4th biggest primary energy source after oil, coal, and natural gas. However, the share of biomass in electricity generation is almost negligible and the most of the biomass energy is directed to either heat generation or biofuel production. On the other hand, power generation based on fossil fuels creates serious global problems such as the increasing greenhouse gas emissions and foreign dependency on supply of fossil fuels. In contrast to fossil fuels, biomass energy sources can be easily found almost everywhere. Since biomass is regarded as an energy source which is renewable, sustainable, and CO_2-free, there have been miscellaneous efforts to incorporate biomass into existing power stations where coal is burned. Co-firing systems where the blends of coal and biomass are burned have been of great importance to achieve this target. Co-firing of coal with biomass has been performed via three options such as direct co-firing, indirect co-firing, and parallel co-firing. Of which, the direct co-firing is by far the most common method that enables to use biomass up to 3% on energy basis. Differences between the structures and the thermal reactivities of biomass and coal restrict to further increase the share of biomass at direct co-firing. On the other hand, indirect co-firing covers gasification of biomass into a fuel gas to provide high degree of fuel flexibility, and the share of biomass could be enriched in this way up to 17% in Lahti plant in Finland. Besides, parallel co-firing systems rely on installation of a separate biomass boiler and utilization of the steam produced in the coal power plant system.
Despite the huge worldwide potential, almost all of the biomass species are usually accompanied by more or less some drawbacks such as low bulk density, low calorific value, high moisture and volatile matter contents, etc.. Moreover, the oxygen content of biomass is typically high and it results in formation of large amounts of volatiles. That's why the biomass firing systems require larger freeboard volumes compared to coal combustors for efficient burning. High contents of oxygen and volatiles also make biomass thermally very reactive that causes segregation of coal and biomass from each other in co-combustion. Such problematic characteristics of biomass necessitate taking effective measures in design and operation. Improvement techniques applied to biomass commonly base on thermal treatment methods by which weak ether bonds that interconnect the macromolecular ingredients in biomass are broken down along with effective De-oxygenation is achieved. Torrefaction and carbonization are two of the well-known techniques

applied to biomass to obtain bio-char/charcoal which has improved fuel properties. Of which, torrefaction is a mild thermochemical treatment where biomass is heated under in an inert environment at atmospheric pressure with relatively low heating rates (<50°C/min) to a temperature which is generally lower than 300°C to decompose most of the hemicellulose content while cellulose and lignin are affected only to a lesser extent . In this way, a dry and partially carbonized solid that has a higher energy density on the mass basis is formed. Biomass also losses the hydrophilic nature after torrefaction and the obtained bio-char is hydrophobic that eliminates the decomposition of the molecules in biomass by bacterial attack. Besides, torrefaction also improves the grindability characteristics of Biomass.

1.1 Objective

The prime objective of this project is to develop an efficient design for torrefaction unit to produce charcoal. The project mainly aims:

1. Performance analysis of torrefaction unit using lens
2. Performance analysis of parabolic trough with secondary reflector.

1.2 Scope of the Project

The design of solar torrefaction unit is proposed in this project can prove to be more efficient than other biomass pretreatment methods. This can redress the problems of biomass pretreatment methods and thus prove to be more efficient pretreatment method. Is carried out in atmospheric temperature that is absence of oxygen so choose solar energy for torrefaction purposes.

1.3 Problem identification

Biomass has some disadvantages when used as fuel, such as its low HHV, high moisture content, hygroscopic nature, smoke emission during combustion, its heterogeneous and uneven composition, and transport difficulties. In order to address the above problems, biomass needs to be pretreated to improve its quality for efficient energy conversion. Existing technologies to improve biomass for energy include thermochemical and biochemical processes.

Torrefaction is a method of biomass pretreatment. Various methods are used for biomass pretreatment such as pyrolysis gasification and torrefaction. Torrefaction is an effective and low temperature process. Other methods require high temperature long process. Torrefaction is mild form of pyrolysis, thermo chemical pretreatment method.

2. Design Basis

Design of torrefaction unit using solar energy is proposed in this research work. Solar radiation is concentrated in to the surface. A parabolic trough collector is used for this purpose. Copper plate and a copper tube are placed at the focus of the parabolic trough. There are two key phenomena that need to be understood in order to comprehend the design of parabolic trough. One is that the shape of parabola must be such that incoming ray's which are parallel to the trough axis will be reflected towards the focus, no matter where on the trough they arrive. The second key is that the light rays from the sun arriving at the earth's surface are almost completely parallel. So if trough can be aligned with its axis pointing at the sun, almost all the incoming radiation will be reflected towards the focal point of the trough. Imperfections in the parabolic shape and imperfect reflections, directly or indirectly contribute to most of the losses. The figure 1 shows the schematic of parabolic trough collector.

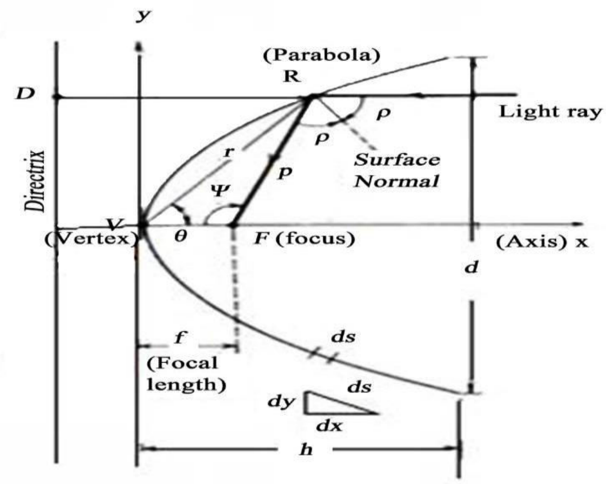

Fig1 Schematic of Parabolic Trough[1]

The biomass considered for design is wood and tomato peels, with a moisture content of m% . hence ½ kg of wood with moisture content of (0.5- m)/100 kg of dry wood and *m*/100 kg of water. It is assumed that the moisture content is totally removed when the wet wood is heated from ambient temperature to 100˚. Hence the energy required for drying 1/2 kg of wet wood is given by:

E_{drying}= (0.5-m)X C_pX (100-t_i)+mXC_{pw} X(100-t_i) +L

Where, t_i = ambient temperature, C_p = specific heat of wood = 1.76 kJ.kg.k, C_{pw} = specific heat of water = 4.186 kJ. Kg. k, L = heat of vaporization = 2265 kJ/kg.

Torrefaction is an endothermic process requiring about 600 - 1000 kJ/kg. The energy which torrefaction reaction absorbs is assumed to be 600 kJ/kg [1]. Hence energy required for torrifying 1/2 kg of dry wood is given by;

$E_{torr} = (0.5\text{-}m) X\ C_p\ X\ (T_t - 100) + 800$

There for, total energy required is

$E_{tot} = E_{drying} + E_{torr}$

Moisture content of wood;

$M_w.(w.b.)\% = \frac{W1-W2}{W1} \times 100$

W1=weight of sample before torrefaction

W2=weight of sample after torrefaction

Sample Calculation:

Assumptions; moisture content of wood= 20%, rim angle= 90°, aperture diameter= 1m, focal length= 0.25 since (f/d= 0.25 for rim angle= 90°)

$E_{drying} = 0.3\ X\ 1.76\ X\ (100\text{-}34) + 0.2\ X\ [4.186\ X\ (100-34) + 2265]$ [1]

$= 562.21$ kJ/kg

$E_{torr} = 0.3\ X\ [1.76\ X\ (250\text{-}100) + 600]$

$= 259.2$kJ/kg

$E_{tot} = 821.416$kJ/kg

3 Principle of Working

This design is a method for drying and torrefying biomass using solar energy integrated with water filtering system. It includes parabolic trough, secondary reflector, lens and a copper tube. The parabolic trough and the reflector are made with stainless steel. The secondary reflector is placed parallel to the focal point of the collector. The solar radiation is captured by the parabolic trough collector is covered with highly reflective material to allow light to be reflected on the focal point. The biomass is placed in the collector area for drying the biomass near the drying area copper tube is placed the incoming water is circulate through the tube and the hot eater is filtered using the filter inside the water tank. Lens is attached with the collector for torrefaction purposes lens move with suns direction. The system is controlled using microcontroller ATmega16 for controlling the tracking of collector and display the temperature. Figure 2 represents the proposed system.

Fig2.Proposed system

4 Results

The main aim of the project was to propose a low temperature biomass pretreatment method using solar energy known as torrefaction. While framing the design idea of solar torrefaction unit, the main focus was given to, the best possible ways of heating biomass using lens. Experiments were carried on different biomass materials and comparing the result with the stand alone torrefaction unit and the performance analysis of lens were carried out in same unit. The reason for choosing lens for the torrefaction purposes is that, concentrating more solar power on the biomass materials and it reduces the time of torrefaction. The figure 3 and 4 represents the torrefaction result of wood and tomato peels.

Fig3. Wood Before and After Torrefaction

Fig.4 Tomato Peels Before and After Torrefaction

5 Conclusions

The research project was aimed at developing a solar torrefaction unit coupled with double reflector. Main focus has given to the performance analysis of lens and parabolic trough with secondary reflector. Magnifying lens was chosen for this research work, the lens chosen was found that more efficient for torrefaction purpose. Torrefcation unit with water filtration system is proposed in this research work. The torrefaction unit with water filtering system was designed and fabricated. Experimental analysis was done and results were obtained. Experiments were carried on different biomass materials and the performance analysis of parabolic trough with secondary reflector done using the application of water filtration. The results obtained showed good agreement with theoretically anticipated results. It was found that the torrefaction of biomass with lens and parabolic trough collector have improve the biomass properties rather than other pretreatment methods of biomass and found that the increasing efficiency of parabolic trough with secondary reflector. The torrefaction temperature for half kilo teak ranges from 75℃ to 90℃ and half kilo tomato was ranges from 65℃ to 80℃. From the obtained result the efficiency of parabolic trough with secondary reflector is about 30%. Found that the mass yield decreases with increase in torrefaction temperature.

6. Acknowledgements

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