Biomass Conversion Technology

Control and Optimization of the Fluidized Bed Gasification

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Summary:

This project and investigation deal with renewable energy. Fossil fuels are a problematic issue for the environment and economy of the developed and under developing countries in recent years.

This project tries to find a solution to convert all kinds of biomass to biogas. Then the economical and optimal operation of the process will investigate theoretically and practically to deliver the applicable biogas to industry.

Overview of the problem:

Soon as a steady increase in worldwide energy demand, global gas emissions are the crucial point in the economic and industrial development of all countries. The standards of living of a country depend directly on the increasing demand for all kinds of energies. However, the worldwide energy demand increases at an alarming rate by industrialization and population growth of the emerging country. With no change in the policies that affect energy consumption all around the world, it is anticipating that energy demand surges up with apps. 44% from the current total of 138.000 TWh to 198.000 TWh by the year 2030 [1]. The world energy outlook (WEO) 2012, published by the International Energy Agency (IEA), has cited that fossil fuel will remain the main source of energy with the app. 80% by the year 2035 [2].

The "450" scenario considers the goal of limiting the global increase in average temperature to two degrees Celsius (2℃). According to several studies concerning climate change, to reach this global limitation of CO_2 concentration in the atmosphere about "450" ppm is necessary. Previously mentioned problems concerning the future energy supply and especially the rapidly increasing amount of CO_2 in the atmosphere have impelled the researchers to develop new and efficient converting technologies for wide use of alternative sources such as biofuels, solar, wind, and hydrothermal energy.

In the future, energy scenarios, based on renewable sources a major role in energy production has pointed to biomass. On the other hand, the unique characteristics of biomass as the only renewable and carbon-based make biomass the most attractive source for future energy purpose. Biomass can convert into usable energy via combustion, biochemical, or thermal conversion process. Moreover, biomass as an energy source shows some typical characteristics that make it special but complicated fuel for the future. Biomass has a carbon-neutral behavior if grown sustainably, its production and application produce almost zero amount of CO_2 that means complete climate-neutral carbon cycle of CO_2.

To sum up, all the industrial countries are going to develop using renewable energy for the whole or parts of their industries. It is worth investing and developing renewable energies especially biomass

conversion technologies as there are various sources of biomass in the country such as (marine algae, residue from forest and agricultural biomass, waste from pruning nut shells, rice husk, etc.) [3].

Work plan:

For use biomass to get energy, conversion processes separated into two main routes of biochemical and thermo-chemical. Any kind of process consists of any enzyme digestion to decompose organic materials categorized under biochemical rout. On the other hand, combustion, pyrolysis, gasification, and hydrothermal carbonization in which heat has utilized to decompose organic matter through chemical reactions known as thermo-chemical route [4]. Thermo-chemical processes are mainly using pretreatment of biomass followed by heating up to a high temperature. Optimizing of the process contains proper controlling of operational conditions such as the amount of gasifier geometry, temperature, pressure, etc. I have planned to use the gasification process to obtain energy from biomass. In gasification, process biomass converts into useful energy products, mostly hydrogen gaseous products, which can convert to higher benefit products such as bio-fuels through Fischer-Tropsch synthesis plants or pure hydrogen production through water gas shift reaction units. In this way, the gasifier divided into three main groups of a fixed bed, fluidized bed, and entrained flow gasification.

In my project, I have planned to optimize fluidized bed gasification by considering the influence of gasification medium (air, oxygen, steam) on product distribution. Data could gather from proper practical experiments and software modeling and simulation of the process (MATLAB) or even by peer literature review by other researchers from around the world. Data help to design a proper control system for operational conditions to get a higher value syngas. Furthermore, this investigation enables us to go through the optimum operation in further studies.

In this study, the main definition of gasification considers. The structure of various biomass notice to obtain a proper model of biomass because the structural decomposition of biomass depends on temperature. Analyzing the data from various biomass give a range of temperature needed for gasifier (mainly between 300˚C to 900˚C).

Then the chemical reaction considers because the amount of the medium such as oxygen, air, or steam and temperature directly has an influence on the output syngas and its quality.

The data show us the proper amount of medium and reaction temperature is needed to optimize and control the process to obtain high-quality syngas. Also, various bed materials use as a catalyst that influences the chemical reactions and finally both the overall performance and efficiency. Previous experiments have shown that using air as mediums mostly uses for processes up to about 50 MWth with net CV of 4-6 MJ/m^3. Also, gasification with oxygen gives a gas with a net 10-15 MJ/m^3 and with steam, 13-20MJ/M^3 [5].

As mentioned the generated gas effected by multiple parameters. The gas composition is also a function of gasifier design and configuration. That's why proper control of a gasifier is necessary. Data gathered from previous steps used to define three main parameters to optimize the process:

- Effect of reactor temperature on the process and product distribution.
- Effect of equivalence ratio (ER) defined as air to fuel ratio on the product distribution.
- Effect of steam on the gasification process and product distribution.

The effect of these parameters analyzes with charts and tables to define the range of mediums optimize the process. In the next part of the project control of the gasifier considers.

Two kinds of fluidized bed (Bubbling and circulating bed) with various operational parameters such as reaction temperature and gasifier agent exists. To optimize and control the gasification process basic criteria of study is categorized below:

- Syngas output temperature and LHV of produced gas study to design a proper control system
- The selection of the controlled and manipulated variable is necessary and has great importance
- To get numerical values of reliability it is necessary to perform process control total mass balance, component mass balance, and energy balance calculations.
- The most important goal is the protection of persons and equipment.

In addition, the minimum sets of variables, that contain sufficient information about the history of the system to compute the future state describe. The differential equation may operate units in ordinary or partial differential equations and dynamic behavior of a process and control system may found by these equations. In chemical process Laplace transformation used. Moreover, the use of state variables and state equation is the most commonly used method of describing a chemical operating system. After selecting controlled and manipulated variables, the degree of freedom defines. Then the process model to picture of measuring devices and processes, constant parameters, manipulated variables, controlled variables, and disturbance variables. In the next step variables with high influence on the process select as parameters that define the character of the process. Obviously, they are in relation to energy and mass balance. These are the variables that determine the control system that should install on the reactor.

Theoretical energy and mass balance of the process followed by using the theory of the control for circulating fluidized bed. Matrix of interaction (RGA) measures and calculates for all possible single input single output (SISO) pairing between a set of variables. By this calculation and mathematical model provided, the interaction between parameters, control loops, and controlled variables for optimum output gains (models will be done by Simulink). Moreover, more Simulink models develop and more pairs of variables will investigate. Also, by developing a steady-state equation and Laplace transformation function, gain matrix (k) calculates providing a zero model to predict possible products of gasification with different portions of air or steam.

Outcome/expectations:

Gasification is one of the unique conversion technologies to produce biogas from biomass. Biogas mostly composed of carbon monoxide (CO), hydrogen (H_2), methane (CH_4), and carbon dioxide (CO_2). In addition, biogas contains sulphuric compounds (SO_2), nitrogen oxide (NOx), and particles. The main goal of the project is to optimize and control the performance of the process. The possible outcome of the project categorized below:

- It is expected that the investigation shows the structure of biomass and the range of temperature needed for the decomposition of its structure in each gasification process.
- It is expected that by modeling and gathering data followed by scientific analysis on charts and tables the optimized range of gasification medium (oxygen, air, and steam), operational

temperature, and pressure determine in order to reach an optimized process for targeted output syngas and application. Also, it is expected that for fluidized bed reaction temperature be around 700˚C - 900˚C. Also, air and steam uses as gasifier medium and equivalence ratio expected to be around 0.27 to 0.37 for optimized and economical operation of circulating fluidized bed. Moreover, the LHV of produced gas expected to be around 3-8 MJ/kg.

- It is expected that mathematical operations use to design the efficient control system to remove tar, particulates, and CO_2 as much as possible from the output syngas and improve its calorific value.

All told, it is expected from the mathematical model, the chemical state, and relative gain array (RGA), the mass of air, the mass of steam, syngas output temperature and volume of output syngas are determined as control variables of the process to set up the control loop and proper instruments.

References:

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