

Simulation Of Biomass Pyrolysis And Gasification

Muhammad Aqeel , Dr. Noor Fitrah

Faculty of Chemical Engineering, Universiti Teknologi Mara

Abstract— This research details the simulation of pyrolysis gasification by aspen plus software. The pyrolysis and gasification of biomass produces syngas which is a source of fuel. The temperature at which the pyrolysis was simulated is ranged between 300-450 °C. this is to maximize the production of syngas. In doing this the selection of reactors to run the simulation was done carefully and a choice of the RSTOIC, RYIELD and RGIBBS was made. This simulation is limited by the raw feed composition as different feeds have different ultimate and proximate analysis data which is of importance especially in simulating pyrolysis and gasification. This research utilizes FORTRAN codes to facilitate in calculations of conversions.

Keywords—

Aspen Plus
Biomass
Drying
Straw Wheat
Pyrolysis And Gasification
Process Simulation

I. INTRODUCTION

The main source of fuel in this modern age comes from fossil fuels. Fossil fuels are fuels that are derived from remains of living organism millions of years ago. Fossil fuels have been used for many years in many fuel powered industries as a source of energy and its reserves are dwindling. As the process of formation of fossil fuels to form take a considerable amount of time, millions of years, it is obvious that an alternative source of energy has to be considered. As of late, biomass has been considered a top contender as a new alternative fuel source.

Biomass is organic matter that originates from living matter. The advantages of biomass are plenty. One of these advantages is that biomass utilizes carbon in a cycle. What this means is as biomass grows, as an example, plants, they use up carbon dioxide. When they die, they are burned as biomass and produce carbon dioxide which forms a balanced cycle of carbon where they produce, and use up carbon dioxide, thus not contributing to pollution. This is also a reason why biomass has been known since as a renewable fuel source. Fossil fuels however, also produce carbon compounds as they are burned, but these carbon compounds do not return to the earth, instead they linger in the atmosphere, polluting the ecosystem. Another advantage of biomass is its abundance compared to other fuel sources. A plethora of industries produces waste in the form of either manure, wood chips, organic compounds such as husks and many others. These are all sources of biomass and as we know waste materials or side products like these, will always be produced.

The way that biomass can be used as a fuel source is not as simple as burning biomass. Biomass has to be converted into

syngas, or producer gas, to be cooled down to form a liquid and to be used as a form of fuel. The process of converting biomass into syngas is called pyrolysis and gasification of biomass.

This research was done to simulate the pyrolysis gasification of biomass by using aspen plus software. The process of pyrolysis and gasification of biomass occurs in sequence, firstly pyrolysis and followed by gasification. Pyrolysis of biomass is to be simulated first as pyrolysis breaks down biomass into constituent elements. This is an important step as this enables gasification to be done. Gasification is where the broken down biomass constituents is converted to syngas, which is made up of mainly carbon monoxide, carbon dioxide and hydrogen.

The simulation of this process of pyrolysis gasification of biomass will be done by using aspen plus version 8.8. this study will focus on the simulation of biomass pyrolysis and gasification and the production of syngas, the fuel source that it produces.

II. METHODOLOGY

A. Materials.

Biomass refers to many types of materials. To specify this simulation, straw wheat was selected as the subject material. Straw wheat was selected as the subject material because of its abundance and to simulate a readily available source of biomass undergo biomass and gasification.

B. Simulation Model

In this simulation the property package that was selected is the Ideal property package. The initial Flowsheet is as below in figure 1.

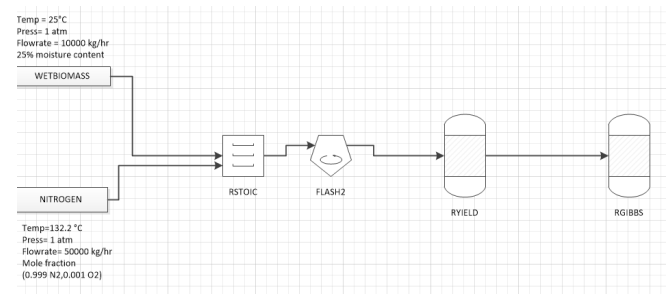


Fig 1: Figure of Initial Flowsheet

The feed into the whole simulation are the wet biomass stream and the nitrogen stream. The nitrogen stream acts as a drying medium and is called a purge medium. The simulation consists of 3 major sections. The drying, pyrolysis and gasification section. All these parts work together to simulate the conversion of biomass into syngas.

Drying of the raw feed in this simulation is an important step. This is because as the initial moisture content of the raw feed is higher than the normal moisture content when compared to other biomass pyrolysis and gasification examples. The drying section consists of 2 equipments. The first equipment is a dryer. The dryer

used in this simulation is a RSTOIC block. RSTOIC block is chosen as a dryer due to the fact that the separation of water in the raw feed (straw wheat) comes from its moisture content. This means that the separation of water from the raw feed is simulated as a conversion process in the RSTOIC [1]. The RSTOIC block converts part of the moisture content in the raw feed into water. this is done with the help of the WATER calculator block. The WATER calculator block utilizes a FORTRAN code to execute a conversion calculation to convert part of the moisture content in the raw feed into water by using the proximate analysis of the biomass. the second part of the drying section is the FLASH2 separator block. The FLASH2 separator functions as a separator to separate the water formed from the dryer, the nitrogen and oxygen from the nitrogen stream, from the dried biomass. the dried biomass is then sent to the pyrolysis section to be broken down.

The pyrolysis section consists of the main RYIELD block and a minor COMBUST block. The reason the water, nitrogen, and oxygen is separated from the biomass is because in the RYIELD block, the only component in the entering stream should be biomass due to the requirement of the RYIELD block. As the feed of biomass enters the RYIELD block, the COMBUST calculator which utilizes the FORTRAN code, computes conversion calculations based on the ultimate analysis of the biomass to break down the biomass into its constituent elements [C, H, O, N, S, Cl, and Ash]. This breakdown into its elements is only possible due to the RYIELD block functioning as a decomposer, working in tandem with the calculator block [3]

The gasification section consists of a single equipment which is the RGIBBS reactor block. The RGIBBS reactor block is involved with converting the constituent elements from the pyrolysis section into syngas which mainly consists of carbon monoxide, carbon dioxide, and hydrogen. The RGIBBS reactor utilizes the heat stream from the RYIELD reactor to simulate this process.

C. Data

The data needed for this simulation to be used in the reactor models are the Ultimate, Proximate, and Sulfur Analysis. The proximate analysis data is shown in table 1 below and is used in the dryer section, whilst the ultimate analysis data is shown in table 2 below and used in the RYIELD reactor below which is part of the pyrolysis section. The sulfur analysis data was also obtained to calculate the production of sulfur compounds later on in the gasification section and its data is shown in table 3 below. The data were obtained from an energy journal [4].

Table 1: Ultimate Analysis Data

Components	Weight Percent (%)
Moisture	25
Fixed Carbon	6.4
Volatile Matter	77.3
Ash Content	16.3

Table 2 : Proximate Analysis Data

Elements	Weight Percent %
Carbon	47.2
Hydrogen	5.8
Oxygen	39.56
Nitrogen	0.7
Sulfur	0.17
Chlorine	0.17
Ash	6.4

Table 3 : Sulfur Analysis Data

Elements	Weight Percent %
Pyritic	0.05
Sulfate	0.06
Organic	0.06

III. RESULTS AND DISCUSSION

A. Final Simulation Flowsheet

The simulation Flowsheet is finalized with the addition of the calculator block and the insertion of the data required. The final Flowsheet Is shown in figure 2 below

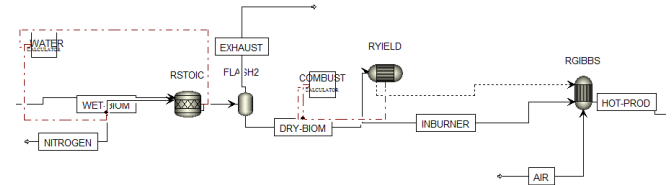


Fig 2: Final Flowsheet

B. Drying Section Data

As we can see from table 4 below, the simulation has removed part of the biomass's feed moisture content and converted to water. The total mass balance for the whole drying section is $10000 + 50000 = 51847.8 + 8152.17 = 60000 \text{ kg/hr}$

Thus the mass balance for streams is balanced. The set moisture content of the raw feed is 25%, while the targeted set moisture content is 8%. Inserting this into the formula below

$$\frac{\text{moisture content in} - \text{moisture content out}}{100 - \text{moisture content out}} = \text{conversion factor of biomass to water}$$

$$\frac{25 - 8}{100 - 8} = 0.18472$$

$$0.18473 \times 10000 = 1847.3$$

Thus the moisture content removal is also verified.

It is also observed that the dry biomass stream only contains biomass, thus fulfilling the function of the drying section. This also allows the pyrolysis section to be run properly without errors.

Stream	wet biomass (10,000)	Nitrogen (50000)	Exhaust (51847.8)	Dried Biomass (8152.17)
Components (in kg/hr)				
Biomass	10000	0	0	8152.17
Nitrogen	0	49950	49942.9	0
Oxygen	0	50	57.1051	0
Water	0	0	1847.83	0

Table 4: Drying Section Data

C. Pyrolysis Section Data

The pyrolysis section is made up of the DRY BIOM stream, the RYIELD reactor and the INBURNER stream.

Stream	Dry-biomass (8152.17)	Inburner (8152.17)
Component (Kg/Hr)		
Biomass	8152.17	0
Water	0	652.174
Nitrogen	0	52.5

Oxygen	0	2967
Sulfur	0	12.75
Hydrogen	0	435
Chlorine	0	12.75
Carbon	0	3540
Ash	0	480

Table 5: Pyrolysis Section Data

As we can see in table 5, total mass balance around the pyrolysis section is equivalent to 8152.17 kg/hr.

The biomass is converted into its constituent elements. The summation of all the constituent elements does total up to 8152.17kg/hr thus verifying the success of the simulation.

D. Gasification Section Data

The gasification section consists of the inburner stream, an air stream, the RGIBBS reactor and a hot-product stream.

Stream Component (Kg/Hr)	Inburner (8152.17)	Air (90000)	Hot-Prod (98152.2)
Biomass	0	0	0
Water	652.174	0	4536.21
Nitrogen	52.5	69037.5	69006.8
Oxygen	2967	20962.5	10941.7
Nitrogen Dioxide	0	0	0.625954
Nitrogen Monoxide	0	0	177.857
Sulfur	12.75	0	0.000664
Sulfur Dioxide	0	0	25.328
Sulfur Trioxide	0	0	0.181545
Hydrogen	435	0	0.0201728
Chlorine	12.75	0	0.000229312
Hydrogen Chloride	0	0	13.1123
Carbon	3540	0	0
Carbon Monoxide	0	0	12969.4
Carbon Dioxide	0	0	1.04993
Ash	480	0	480

Table 6 : Gasification Section Data

As we can see the summation of the components in the hot product stream is equivalent to the value of the mass flow of the in burner and the air streams as seen in table 6 above.

To verify the production of syngas compared to successful simulations, the weight percent of the syngas (carbon monoxide, carbon dioxide and hydrogen) in the hot-product stream was calculated and its results were compared against reference data [5]. The results are shown in table 7 below.

Data Components	Reference Data (weight percent%)	Simulation Data (weight percent %)
H ₂	19.52	2.0552e-4
CO	12.57	13.21
CO ₂	17.57	0.011

From the results we can see that the RGIBBS reactor has produced a very different result compared to available reference data. This difference can be caused by the difference in feed as the reference data is from a general biomass simulation, where the specific type of biomass is not specified. The specification of straw wheat as is done in this simulation, utilizes a different ultimate analysis, proximate analysis, and therefore a different heat of combustion which may influence the difference in change. The RGIBBS reactor also takes into account the possible products that was inputted into it and depending on the parameters, produces the desired products.

IV. CONCLUSION

In a nutshell, a source of an alternative fuel source must be utilized and biomass is a good start. Biomass can produce approximately a collective 14 percent by weight of syngas from raw feed worth very little. In production of syngas from biomass, the raw feed selected must be thoroughly researched in order to provide the most amount of syngas product and in turn produce more energy.

It is seen here that even though in this simulation a small amount of syngas is produced, it shows a positive step in the right direction to a more sustainable source of energy

ACKNOWLEDGMENT

In preparing this research report, I was guided by my supervisor, assisted by colleagues and many researchers. I would like to thank my supervisor, Dr. Noor Fitrah for her outstanding advice, guidance and encouragement in carrying out the research and execution of this project. and University Teknologi Mara for the opportunity, and finally, I would like to thank my parents for the patience and support I received on the course of pursuing my education

References

- [1] Bridgwater, A.V. Review Of Fast Pyrolysis Of Biomass And Product Upgrading. *Biomass Bioenergy* 2012, 38, 68–94.
- [2] Demirbas, A. (2002). Partly Chemical Analysis Of Liquid Fraction Of Flash Pyrolysis Products From Biomass In The Presence Of Sodium Carbonate. *Energy Conversion And Management, Vol. 43, No. 14*, (September 2002) 8 (1801-1809), 0196-8904.
- [3] Encinar, J. M., González, J. F., Martínez, G., & Martín, M. J. (N.D.). Pyrolysis And Catalytic Steam Gasification Of Olive Oil Waste In Two Stages Key Words, 3–8..
- [4] Simulation Of Biomass Gasification In A Dual Fluidized Bed Gasifier, *Biomass Conv. Bioref* 2 (2012) 1-10.
- [5] Zhai M, Et Al., Process Simulation Of Staging Pyrolysis And Steam Gasification For Pine Sawdust, *International Journal Of Hydrogen Energy* (2016)
- [6] Gasification In Interconnected Fluidized Beds, *Biomass Bioenergy* 32 (2) (2008) 120-127.
- [7] T.Kan , V. Strezov Renewable and Sustainable Energy Reviews 57 (2016) 1126–1140.
- [8] J. Mabrouki et al. / C. R. Chimie Simulation of the fast pyrolysis of Tunisian biomass feedstocks for bio-fuel production 19 (2016) 466-474