Simulation Studies of Biomass Gasification System

by

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CERTFICATION OF APPROVAL

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Approved by,

____

Dr Lemma Dendena Tufa

UNIVERSITI TEKNOLOGI PETRONAS

TRONOH, PERAK

MAY 2014

CERTIFICATION OF ORIGINALITY

This is to certify that I am responsible for the work submitted in this project, that the original work is my own except as specified in the references and acknowledgements, and that the original work contained herein have not been undertaken or done by unspecified sources or persons.

RAJA NUR ARIANA BT RAJA AZLAN

ABSTRACT

As the fossil fuels is depleting in this world, renewable energy has become an important source of energy. Biomass gasification is one of the potential technologies that can convert biomass into environmental friendly energy. This technology is the possible method in reducing the emission of CO_2 to environment. Palm kernel shell is used as its feedstock because of its ability of producing high production of hydrogen gas.

This research paper is to develop a model of biomass gasification system which is located at Block P in University Teknologi PETRONAS. To fulfill this objective, information regarding the operating conditions of the equipment, and process flow diagram of the system need to be gathered. With using Aspen Plus software, a simulation model of biomass gasification is developed in this paper. In this research the temperature and steam to biomass ratio are manipulated to see the effect on gas production.

ACKNOWLEDGMENT

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CHAPTER 1

1.0 Background of Study

With global population growth and rising living standards, energy demands have been increase continuously throughout the year. This condition has been a challenge to energy generation industry based on fossil fuels because the main source of energy is depleting. Thus, in the near future, the generation of energy will utilize method that is independent to supply from fossil fuels. One of the solutions is by using biomass gasification.

Gasification is a chemical process that can convert a carbonaceous material into useful chemical feedstock or convenient gaseous fuels. Some of the processes that are involved in this conversion are pyrolysis, partial oxidation and hydrogenation. One special feature of gasification is that this process has the ability to process a wide range of feedstock. Some of the raw material that can be used are coal, heavy oils, petroleum coke, heavy refinery residuals, refinery wastes, hydrocarbon contaminated soils, biomass and agricultural wastes [1]. To process this feedstock, a few choices of equipment can be used such as fixed-bed gasifiers, entrained-flow gasifiers and fluidized-bed gasifiers. Each equipment has its own features and specialised to handle specific feedstock.

Model is a mathematical representation of a system that can be used to reason and make prediction on the behaviour of a system. For a system, multiple models can be created depending on the condition and phenomena of interest on the system. In modelling, it has two types of behaviour, steady state and dynamic behaviour. Steady state is to see a static relation between input and output with respect to time = 0 while dynamic behaviour is the changes of a system that will evolve with time. The changes of input will affect the system; however, the changes will not occur immediately [2].

Biomass gasification system is one of the technologies that can convert biomass into energy in environmental friendly way. It has been a favourite in industry because of its method that can reduce emission of carbon dioxide in industrial energy generation. In recent years, with more awareness and concern about greenhouse gas emission, biomass gasification system is considered to be very promising in generating clean energy. It also does not depend on oil and gas supply, thus, fluctuating price of oil and gas will not affect production of this useful energy. Therefore, it is important to further analyse and optimise the gasification process in order to increase the overall performance of biomass gasification system. This can be achieved by creating a model of this system using software such as Aspen Plus and HYSYS.

1.1 Problem Statement

Simulation of a model is important as it can determine how a system works when variables are manipulated. By altering the input variable of biomass gasification system, production of hydrogen can be analysed. There is a pilot scale of biomass gasification system located at block P, UTP. This gasification system is used to produce hydrogen as energy carrier. However, there is no modelling has been done for this pilot scale. Thus, modelling of biomass gasification system will be developed in the research

1.2 Objective

The objectives of this project is to develop an Aspen Plus model of biomass gasification system. This biomass gasification plant is located at Block P in University Teknologi PETRONAS. To design this model, information regarding this plant is required. The information is gathered from the plant itself and from other references. Apart from that, this research also required to analyse the production of hydrogen when temperature and steam to biomass ratio are manipulated.

1.3 Scope of Study

- Know the process description for biomass gasification system
- Understand the Process & Instrument Diagram of the system
- Create a model based on P&ID of the system
- Add specification on the model created

1.4 The Relevancy of the Project

This project is relevant to Chemical Engineering students because it exposed students to develop their knowledge in the process industry. In this research, students are able to be more familiarize with software such as Aspen Plus and HYSYS. Besides that, students are also able to apply their knowledge in this software to actual plant. This knowledge are beneficial for students when they pursuing in their working life as chemical engineer.

1.5 Feasibility of the Project

This project is feasible as the time given to complete this project is approximately eight months. To ensure that work is done within time frame, Gantt chart is developed. The author use the time adequately to complete the modelling of biomass gasification system.

CHAPTER 2

2.0 Literature Review

2.1 Gasification

A process of converting carbonaceous materials to something useful such as combustible fuel gas or chemical feedstock is called gasification. This process involves carbon to react with medium of reaction such as oxygen, carbon dioxide, air, steam or mixture of these gasses. Basically, carbon material will be heated in a high temperature (1300^{o}F), react with these gasses and produced gaseous products. These products can be used to provide electric power and heat or become raw material to synthesis chemicals, liquid fuels and gaseous fuels [1].

Combustion also converts materials to gases products. The difference of gasification with combustion is gasification can operate at a controlled supplied of oxygen while combustion takes place at oxidizing environment. The objective of conducting gasification is also different compare with combustion. For gasification, its purpose is to convert a feed material into environmental friendly product while the purpose of combustion is to thermally destruct the feed material and generate heat.

In a typical gasification process, there are four main mechanisms that usually occurred [3]:

- Drying process
- Pyrolysis process
- Oxidation reduction
- Reduction reaction or gasification

Moisture content in feedstock usually ranges from 30% to 60% and some may reach up to 90%. Before feedstock is fed into gasifier, feedstock must go through a certain degree of drying to remove as much moisture as possible. Drying zone is where the free moisture will be removed under the heating around 50 to 150^{0}C. After this process, the feedstock will turn into dry material [4].

Pyrolysis process begins at temperature above 160^0C. It involves breakdown of larger hydrocarbon molecules into smaller gas molecules (CO, CO_2, H_2 and CH_4) thermally. In this process, no external agent or other gasifying agent are needed. Generally, the process is expressed in this chemical reaction equation [4].

$$CH_xO_y = n_1C + n_2H_2 + n_3H_2O + n_4CO + n_5\,CO_2 + n_6CH_4$$

The product in this process is classified into three types [5]:

- Solid (mostly char or carbon)
- Liquid (tars, heavier hydrocarbons and water)
- Gas (CO_2, H_2O, CO, C_2H_2,C_2H_4, C_2H_6, etc)

The next process is oxidation reduction process where combustion (exothermic reaction) is occurred in gasifier. With temperature range from 1000^0C to 1200^0C, the heat produced here will provide heating for drying and pyrolysis of feedstock. Below shows the chemical reaction in the zone [4]:

$$C + O_2 \rightarrow CO_2$$
$$2C + O_2 \rightarrow 2CO$$
$$2CO + O_2 \rightarrow 2CO_2$$
$$2H_2 + O_2 \rightarrow 2H_2O$$
$$CH_4 + 2O_2 \rightarrow CO_2 + 2H_2O$$

Gasification process which also known as reduction reaction is a process where chemical reactions of hydrocarbons with gasifying medium such as air, steam or oxygen. Using biomass as feedstock can helps in lowering the temperature in gasification process due to the presence of oxygen in biomass itself [6-7].

The chemical reactions are shown below [4]:

$$C + CO_2 \rightarrow 2CO$$

$$C + 2H_2O \rightarrow CO_2 + 2H_2$$

$$C + H_2O \rightarrow CO + H_2$$

$$CO + H_2O \rightarrow H_2 + CO_2$$

$$CO + 3H_2 \rightarrow CH_4 + H_2O$$

2.2 Biomass

Biomass is an organic material that is formed by interaction of plants and animals with carbon dioxide, air, water, soil and sunlight. It only includes dead biological species that recently dead and living things that can be used as fuels or in chemical production [5]. It is a renewable source and mainly composed of carbon and oxygen. Examples of sources of biomass are:

Type	Examples
Agricultural	Corn stalks, straw, nutshells and food grain
Forest	Trees, wood, sawdust and wood waste
Biological	Animal waste and biological waste

Table 2.1: Example of Biomass

In this project, the biomass that will be using as feedstock is palm kernel shell. According to Abdullah et. All, palm kernel shell has great properties as a feedstock for biomass gasification process [6]. It contains high calorific value which is 20.40 MJ kg^{-1}. Calorific value is close related to amount of gas produce. High calorific value will gives higher calorific value of producer gas. There are two criteria that affect calorific value. The first property that can relate with are oxygen-carbon (O:C) and hydrogen-carbon (H:C) bonds. The lower O:C and H:C ratios, the higher the energy content of biomass. Moisture content also affect the calorific value of a feedstock. Calorific value will be decrease if the moisture content of feedstock is high due to the loss of energy to remove excess moisture in the feedstock. For palm kernel shell, the moisture content in it is 17.50 wt % which is low compare to other biomass such as coconut shell (18.5 wt%), empty fruit bunch (66.26 wt%) and sugarcane residue (52.20 wt%). Other than that, palm kernel shell contains 14.87% of fixed carbon and 81.03% of volatile matter. A high content of these matters can result in more efficient of gasification process because it can be easy to ignited and gasified. Ng et. All has also has stated that the palm kernel shell has gives the highest hydrogen production (28.48 g H_2/ kg palm kernel shell) for gasification compared to bagase, rice husk and coconut shell [7].

2.3 Biomass Gasification Technology

In this recent year, it is a challenge to generate energy using fossil fuels as its sources are depleting while the demand of energy is increasing yearly. Biomass gasification has been identified as a promising technology that can convert biomass into electricity in an environmental friendly way. It is consider environmental friendly because it can reduce the emission of greenhouse gas. This technology has received increasing attention because of the current situation where demands for clean fuels and chemical feedstock are high [8]. By using the renewable source of biomass, gasification will not depend on the supply of fossil fuels or be affected by the fluctuating price of oil and gas.

Gasification is carried out generally in gasifier. There are three major types of gasifiers that can perform gasification process [9-11]:

- Moving bed (fixed bed) gasifiers
- Fluidized-bed gasifiers
- Entrained-flow gasifiers

Moving bed gasifiers which also known as fixed bed reactor is the simplest type of gasifiers. The feedstock will enter from the top and move downwards through the bed while the gasifying agent (oxygen, air, steam) will enter from the bottom of the bed and move upwards. Feedstock and gasifying agent will react with each other and produce product gas which will leaves from top as well. The feedstock will pass through several stages of gasification; drying zone, pyrolysis zone, gasification and combustion zone [12]. At the top most zones, fresh feedstock will be dries from the hot product that comes from bottom. Then, it will be decomposes (pyrolyzed) into non condensable gases, condensable gases and char. In gasification zone, char will be gasified with carbon dioxide and as a result, carbon dioxide concentration is declining in gasification zone. As chars reach the bottom layer, combustion reaction is occurred with presence of oxygen. The advantages of this gasifier are it has high carbon conversion efficiency and possibility in melting the ash [13]. However, this reactor can suffer high tar yields at producer gas.

In fluidized-bed reactor, feedstock is feed from either top or side of the reactor. As feed is entered, it is mixed fast with the whole body of fluid bed. At the bottom part of reactor, gasifying medium is continuously entered. This reactor is considered as in plug flow mode because of continuously feed of feedstock and gasifying medium. When feedstock is in contact with gasifying medium, it is heated quickly to reach the bed temperature. Drying and pyrolysis is proceeding quickly while gas and char are produced. For fluidized bed reactor, the advantage is it has good heat and material transfer between gas and solid phases with best temperature distribution [13]. This makes the heating process faster and more efficient. A fluidized bed reactor is flexible in utilizing different types of feedstock, but it works best in handling biomass [9-10].

Entrained-flow reactor operates with feedstock and gasifying medium enters from top of the reactor. As gasifying medium entered, combustion is taken place. This exothermic reaction occurred rapidly and causes a raise of temperature in the reactor. The temperature will increase till it reach the melting point of ash, thus, it will cause complete destruction of tar.

From the biomass gasification process, ash and producer gas will be produced. Producer gas can be used to run internal combustion engine, can become heating medium (replacing oil furnace) and used to generate electricity [14-15]. The quality of gas produced is depending on the gasifying agent used and the operating condition.

2.4 Modelling of Biomass Gasification

Simulation is usually used during the planning and designing time of a plant or a system while a model is designed to understand the objective of simulation and to make predictions on how a system will behave. Basically, there are two types of models which are static model and dynamic model. Static model is a static relation between inputs and outputs where it will look at the balance of variables in steady state rather than focusing the variables in transient manner [2]. This model uses the equations of material or energy balance as its basis of representation [16]. Dynamic model, in the other hand, is a model that observes changes of the system in time. It can be determine by observing the changes or respond to a step change in control signal. By setting a different signal value to a system, the control will change its value and output is observed [2]. Dynamic model can be represented in the form of differential model.

There is a lot of information that can be determined from a good model. They are:

- Identify the optimum conditions or a design for the gasifier
- Determine the concern or danger in operating
- Can provide information regarding the extreme operating condition
- Provide information for a wider range of conditions

For biomass gasification system, the model required to have the following processes included; biomass drying, pyrolysis, combustion and gasification. Many variables can be manipulated to determine the dynamic behaviour of this system. Examples are type of gasifying agent (air, oxygen or steam), temperature operating and type of feedstock [17]. From the simulation, it can predict the produced gas yield, composition of produce gas and heating value of the system [7,18]. Thus, the optimum condition or parameters can be identified by analysing the modelling results [8].

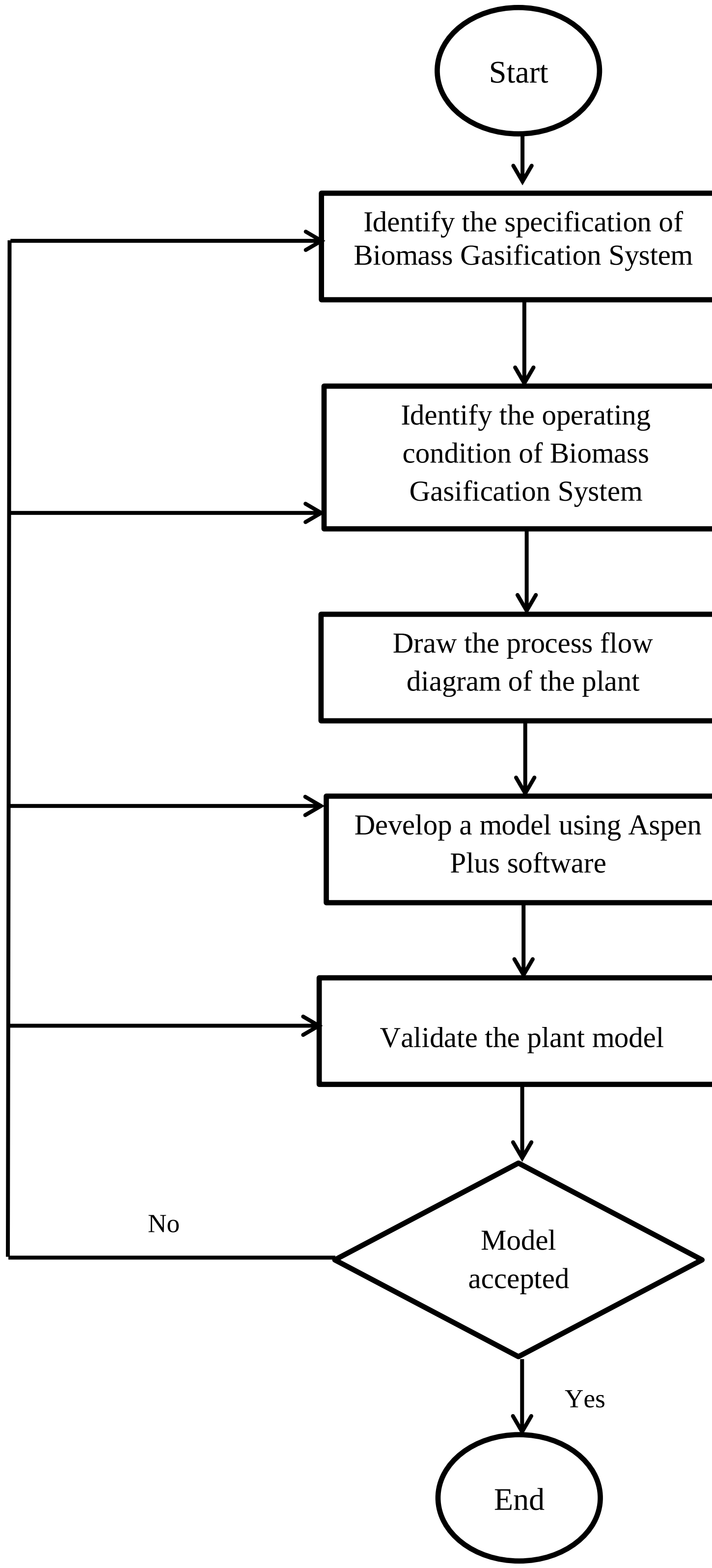
Aspen Plus has been chosen to be used for modelling biomass gasification. According to Julio, this software has the ability to do solid separation which is suitable for gasification process as it has solid products [19]. Che et. All has stated it is more convenient to use Ryield Block of Aspen Plus to simulate pyrolysis process in gasifier [4]. From model that constructed at Aspen Plus, syngas composition, heating values and conversion efficiencies can be determined by changing the manipulated variable. This data can be recorded as the output variable of this simulation.

CHAPTER 3

3.0 Research Methodology

To do simulation, one must be clear with the objective of accomplishing this model. It also needs to know the necessary variable that need to be manipulated and what type of behaviour that will be simulated in the system. Next, information gathering need to be done. Identification of operating condition of a system is important in this step because it is as a preparation for modelling a system. Information regarding biomass gasification system can be obtained from the P&ID of the system and also gathered from some research papers. After getting the important data regarding the system, the model of system can be build. Start with a simple process flow diagram and later, this diagram will be implemented in software. For this system, the software that will be using is Aspen Plus software. Once the model is design in Aspen Plus software, it must be validate with plant data to ensure that the model is valid and reliable. A good model can later be used to study the effect of manipulating variables on gas production.

3.1 Developing Aspen Plus Model of Biomass Gasification System



3.1.1 Biomass as Feedstock

Some data has been collected to conduct this project. One of the information that is required is the properties description regarding the feedstock, palm kernel shell. The table below shows the properties of palm kernel shell.

Palm Kernel Shell	
Moisture (%)	9.61
Volatile matter (wt % dry basis)	80.92
Fixed Carbon (wt % dry basis)	14.67
Ash Content	4.31
C (wt % dry basis)	49.74
H (wt % dry basis)	5.68
N(wt % dry basis)	1.02
S (wt % dry basis)	0.27
O (by difference)	43.36
Higher heating value	18.46
Calorific Value (MJ/kg^{-1})	20.40

Table 3.1: Properties of Palm Kernel Shell

Palm kernel shell is well known for its high calorific value. This property makes it the most suitable in becoming the feedstock of gasification system. The molecular equation for palm kernel shell is $CH_{1.283}O_{0.594}N_{0.031}$ [7]. In the simulation, biomass is feed in according to its composition; C = 49.74%, H = 5.68%, N = 1.02%, S = 0.27% and O% = 43.36%. This composition will represent biomass in the simulation.

3.1.2 Specification of Biomass Gasification System

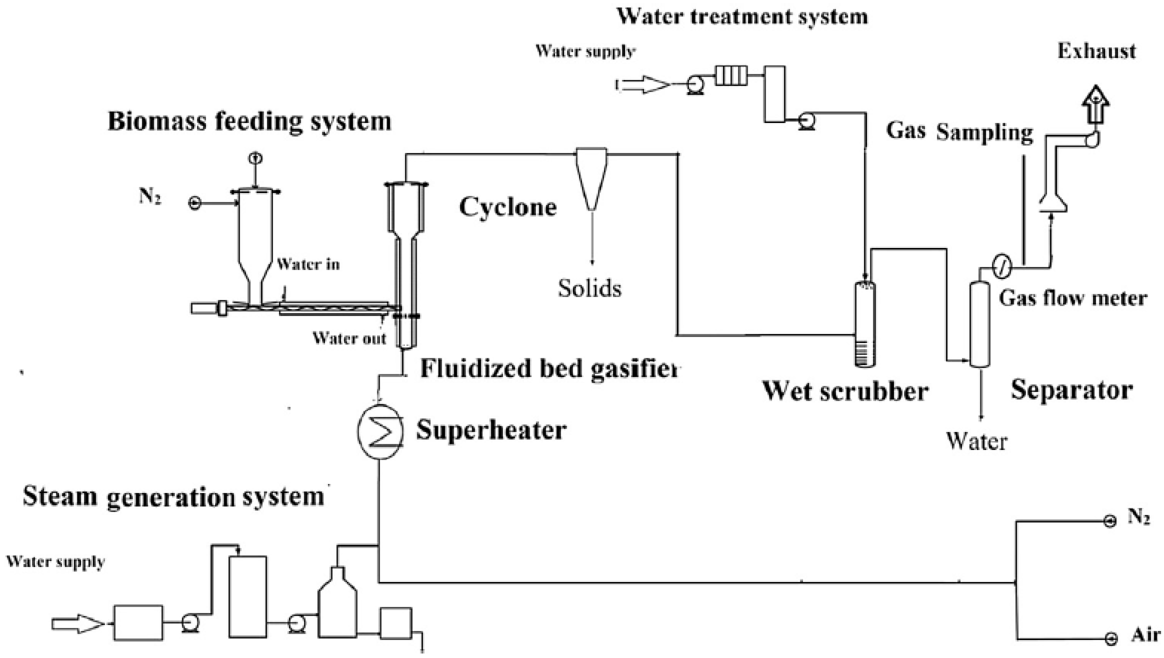


Figure 3.1: Pilot Scale Biomass Gasification System

The figure above shows the diagram of pilot scale biomass gasification system. From the P&ID that is given to the author, the process flow diagram is developed. This process flow diagram will be guidance for proceeding to simulation in Aspen Plus. Basically, this plant is divided into two parts. The first part is the series of three reactors where biomass (palm kernel shell), steam and inert gas are feed in each of the reactor. The first reactor is fluidized bed gasifier while the second reactor is guard bed reactor and third reactor is polishing reactor. These reactors will be explained further in the process flow diagram. Another part of the system is the water management where it will be further divided into two parts; quenching water and steam generation. In quenching water, the water will pass through water treatment system to be used as quenching water in quenching tower. For steam generation, the water will be heated up to become supersaturated steam.

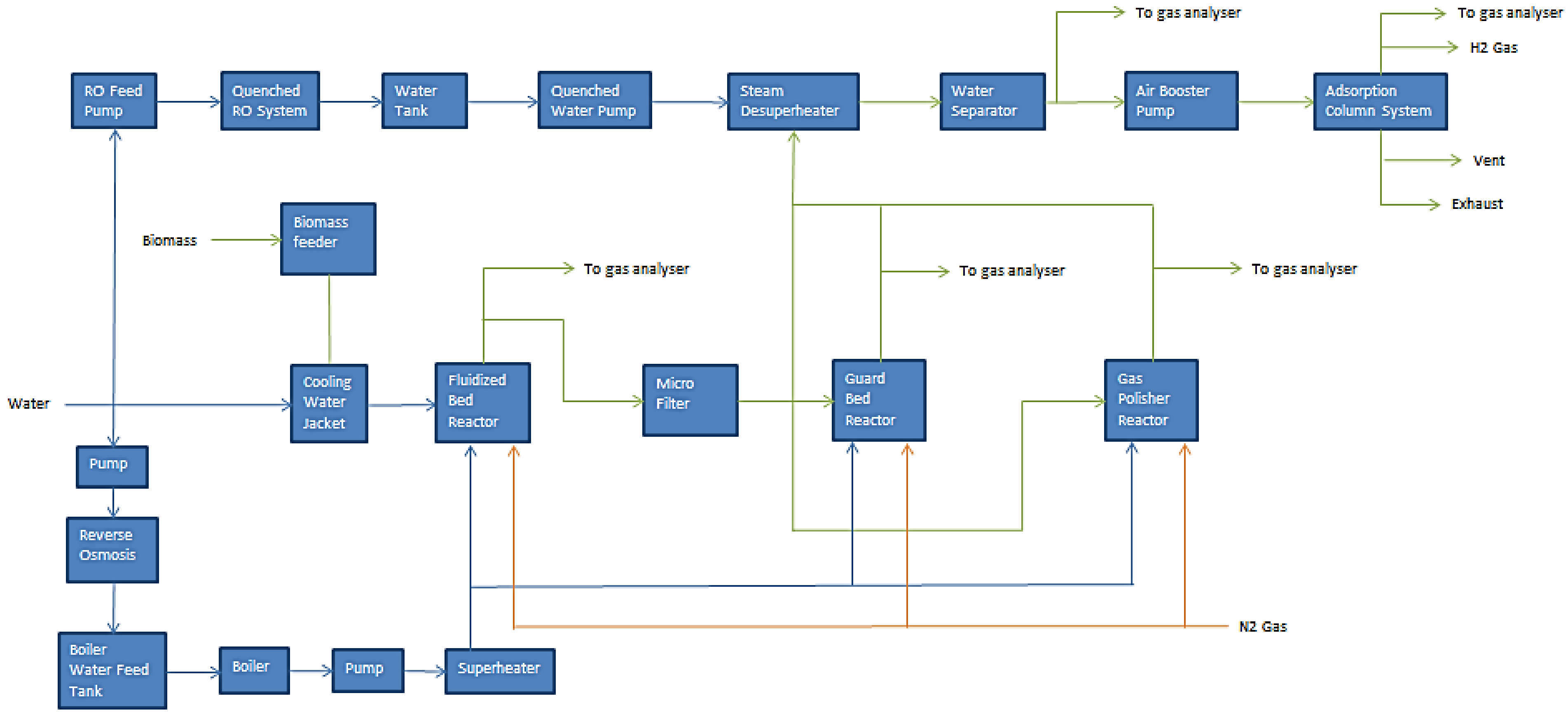
3.1.3 Operating Condition of Biomass Gasification System

The operating conditions are based on actual plant at Block P, UTP. The information are summarize in the table below.

No	Equipment	Parameters			
		Temperature	Pressure	Flowrate	Capacity
1	Cooling Water Pump	25^{o}C	1 barg	600 L/hr	
2	Reverse Osmosis				
3	Boiler Water Feed Tank				100L
4	Pump		8 barg	15L/hr	
5	Boiler	150^{o}C	6barg	8.2kg/hr	
6	Biomass Feeding Hooper	50-60^{o}C			30L
7	Superheater	400^{o}C	6.9barg	1.96kg/hr	
8	Fluidized Bed Gasifier	700^{o}C	6barg		0.044m3
9	Micro Filter	700^{o}C	6barg		
10	Guard Bed Gasifier	700^{o}C	6barg		0.044m3
11	Gas Polisher Reactor	700^{o}C	6barg		0.044m3
12	RO Feed Pump		6.5barg	2m3/hr	
13	Quenched RO System		7barg	0.5m3/hr	
14	Water Tank				0.5m3
15	Quenched Water Pump		6.5barg	2m3/hr	
16	Steam Desuperheater	300^{o}C	6barg		
17	Water Separator	40-50^{o}C	6arg		
18	Air Booster Pump	40^{o}C	5.5barg	8.9m3/hr	
19	Adsorption Column System	40^{o}C	12barg	5m3/hr	8L

Table 3.2: List of Equipment in Biomass Gasification System

3.1.4 Process Flow Diagram of Biomass Gasification System



The diagram shows the process flow diagram of biomass gasification system at Block P, UTP. The biomass (palm kernel shell) is fed in biomass feeder at 1.0kg/hr. At the feeding section, nitrogen gas is injected with the pressure of 3 barg at 7.2m^3/hr to prevent the backflow of biomass. Before biomass is fed in the fluidized bed gasifier, it is passed through cooling water jacket to prevent any decomposition of the biomass itself. At fluidized bed gasifier, biomass, superheated steam and inert gas is feed in. The superheated steam is fed at a rate of 1.96 kg/hr. Steam and biomass will react to produce produced gas such as H_2, CO, CO_2 and CH_4 and also ashes. Some of the gases product is send to gas analyser for further analysis. The analyser is used to measure the concentration of the following gas; H_2, CO, CO_2, N_2 and CH_4. The other products will pass through micro filter with porosity of 50μm to separate solids with gases. Guard bed gasifier is used to crack down 'heavy' gases such as gas tar while polishing bed reactor is used to further polish the product gases. Next, product gas is passed through steam desuperheater (water spray tower) where it will cool down the gas and remove steam. After the temperature of product gas is reduced, it will pass through water separator to separate water and later will go through adsorption column system. From here, hydrogen is released.

For water system management, some of the service water will be used for quenching and other will be used for steam generation. The service water is pump to reverse osmosis equipment where impurities are removed from water. The clean water is then stored in boiler water feed tank. With the flowrate of 8.2kg/hr, water is heated up to 150^{o}C in the boiler. The steam is generated and is further heated up using superheater exchanger to 250^{o}C. This superheated steam is then injected to the bottom of fluidized bed gasifier and react with the biomass.

Another stream of water is used for quenched water system. The water is pump to RO system and is stored in water tank. Later, it is pump at 2m^3/hr with pressure of 6.5barg to the steam desuperheater. This water is used to cool down the product gas.

3.1.5 Modelling using Aspen Plus

<u>Gasifier (Reactor)</u>

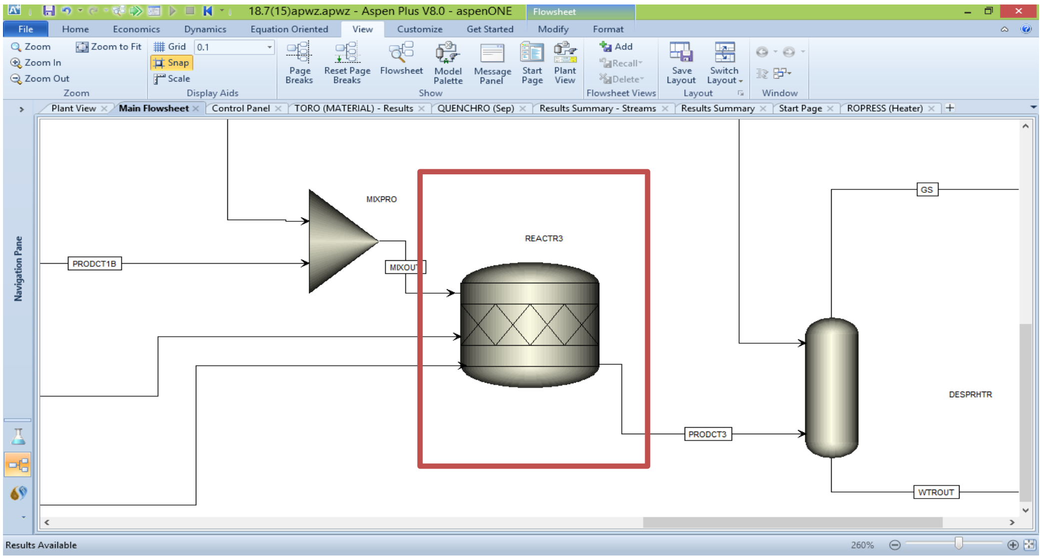


Figure 3.2: RStoic BLOCK

For all three gasifiers in the plant, the units that are used in Aspen Plus are Rstoic BLOCK. This Aspen Plus's reactor block enables the user to include the reactions and conversion occurred in gasifier. The equations that are inserted in simulation are:

$$C + H_2O \rightarrow CO + H_2 \qquad (1)$$

$$C + 2H_2 \rightarrow CH_4 \qquad (2)$$

$$CH_4 + H_2O \rightarrow CO + 3H_2 \qquad (3)$$

$$CO + H_2O \rightarrow CO_2 + H_2 \qquad (4)$$

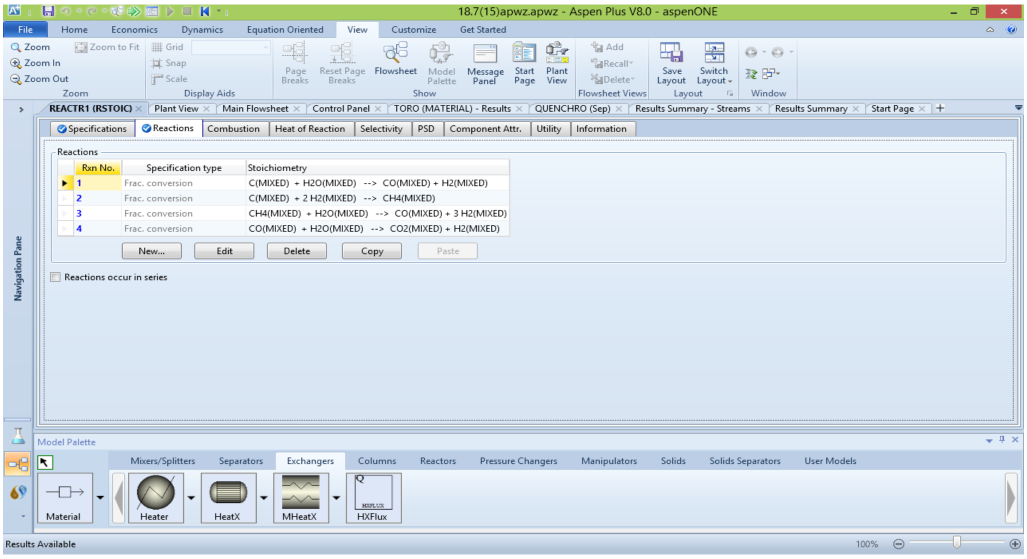


Figure 3.3: Configuration of Equations

Each of the reactor; fluidized bed gasifier, guard bed reactor and polishing reactor have the same operating condition. The operating condition that is used is 700°C for temperature and 6 barg for pressure. The molar flowrate of each reactor is in the table below.

Composition (kmol/hr)	Reactor 1 (Fluidized Bed Reactor)			
	Feed	Steam in	Inert Gas in	Product
C	0.0745	0.0000	0.0000	0.0149
O	0.0244	0.0000	0.0000	0.0244
CO	0.0000	0.0000	0.0000	0.0224
CO2	0.0000	0.0000	0.0000	0.0736
CH4	0.0000	0.0000	0.0000	0.0373
H2	0.0507	0.0000	0.0333	0.0318
N2	0.0007	0.0000	0.0333	0.0340
H2O	0.0000	0.1080	0.0000	0.0856
S	0.0002	0.0000	0.0000	0.0002

Table 3.3: Molar Flow for Fluidized Bed Gasifier

Composition (kmol/hr)	Reactor 2 (Guard Bed Reactor)			
	Feed	Steam in	Inert Gas	Product
C	0.0075	0.0000	0.0000	0.0026
O	0.0122	0.0000	0.0000	0.0122
CO	0.0112	0.0000	0.0000	0.0121
CO2	0.0001	0.0000	0.0000	0.0121
CH4	0.0187	0.0000	0.0000	0.0107
H2	0.0160	0.0000	0.0333	0.0903
N2	0.0170	0.0000	0.0333	0.0503
H2O	0.0429	0.1088	0.0000	0.1268
S	0.0001	0.0000	0.0000	0.0001

Table 3.4: Molar Flow for Guard Bed Reactor

Composition (kmol/hr)	Reactor 3 (Polishing Reactor)			
	Feed	Steam in	Inert Gas	Product
C	0.0100	0.0000	0.0000	0.0035
O	0.0244	0.0000	0.0000	0.0244
CO	0.0232	0.0000	0.0000	0.0344
CO2	0.0121	0.0000	0.0000	0.0268
CH4	0.0292	0.0000	0.0000	0.0098
H2	0.1062	0.0000	0.0333	0.2190
N2	0.0673	0.0000	0.0333	0.1006
H2O	0.1694	0.1088	0.0000	0.2376
S	0.0002	0.0000	0.0000	0.0002

Table 3.5: Molar Flow for Polishing Reactor

From the table, it shows that number of hydrogen is increased from each reactor. This shows the production of hydrogen from each reactor. C (carbon) is decreased in each reactor because of reaction of C (carbon) with water and hydrogen occurred. The highest gas production starts with hydrogen (0.2190kmol/hr), CO (0.0344kmol/hr), CO_2 (0.0268kmol/hr) and the smallest production is CH_4 (0.0098kmol/hr).

Water Remover Unit (Separator)

Separator is used to remove water from gas product. The block that is used is Sep Block where the block can allow split fraction of each components. The temperature input in this unit is at 40^{o}C and 6 barg.

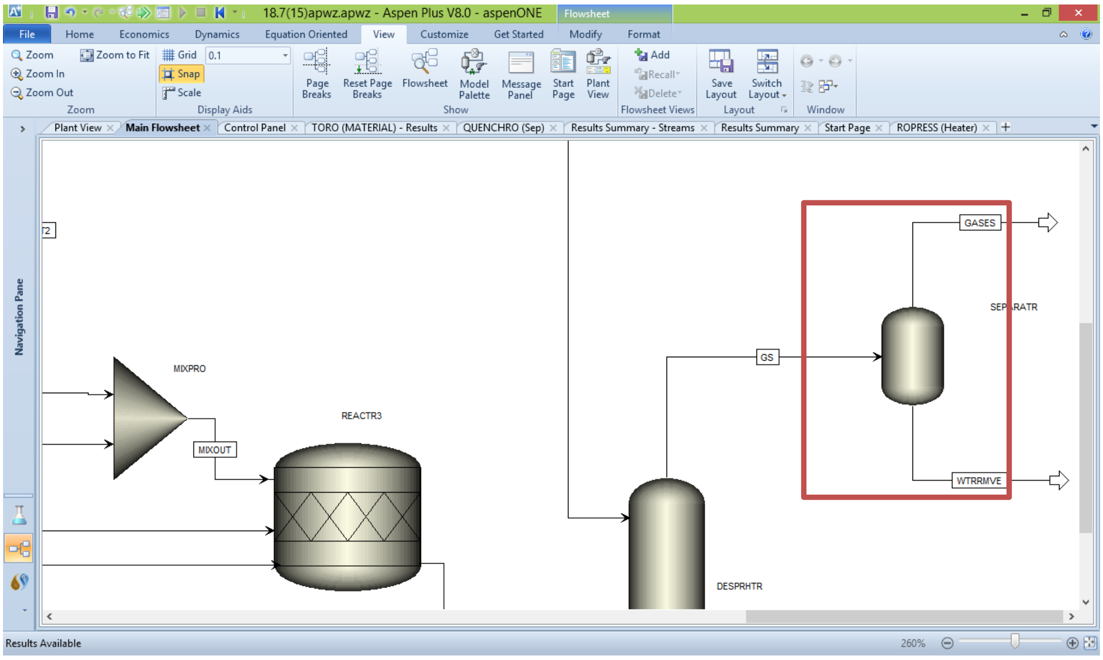


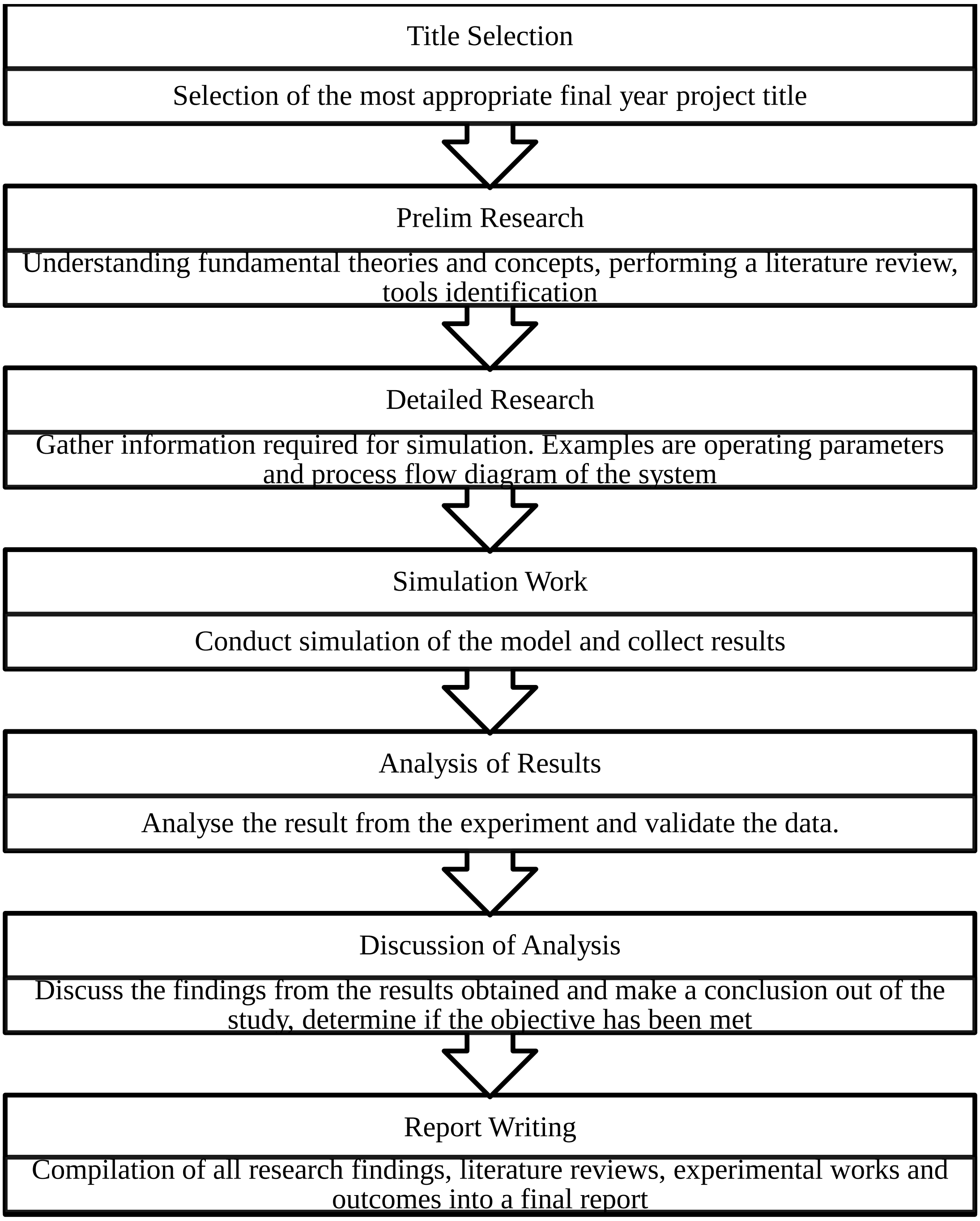
Figure 3.4: Sep Block in Aspen Plus

Composition (kmol/hr)	Water Removal Unit		
	Feed	Product	Water Out
C	0.0000	0.0000	0.00E+00
O	0.0244	0.0243	2.28E-06
CO	0.0344	0.0344	1.22E-07
CO2	0.0268	0.0268	1.04E-05
CH4	0.0098	0.0098	3.62E-07
H2	0.2190	0.2190	1.49E-06
N2	0.1006	0.1006	4.45E-07
H2O	1.5363	0.0039	1.53E+00
S	0.0000	0.0000	0.00E+00

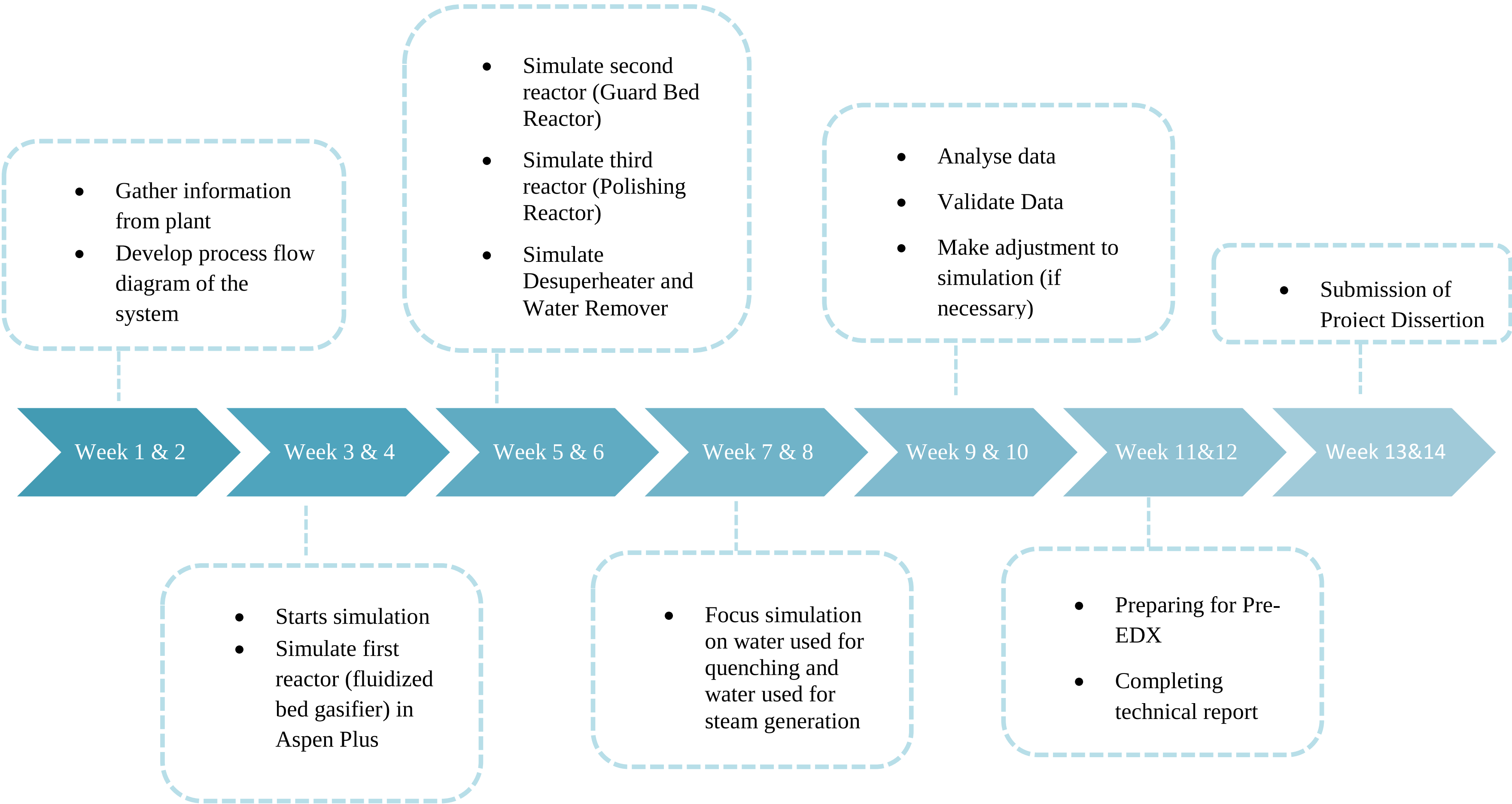
Table 3.5: Molar Flow in Separator

This shows the end result of product gas in Aspen Plus simulation. From the table above, there are small amount of components that are escaped in water out. This is because high efficiency in water separation is difficult to achieve.

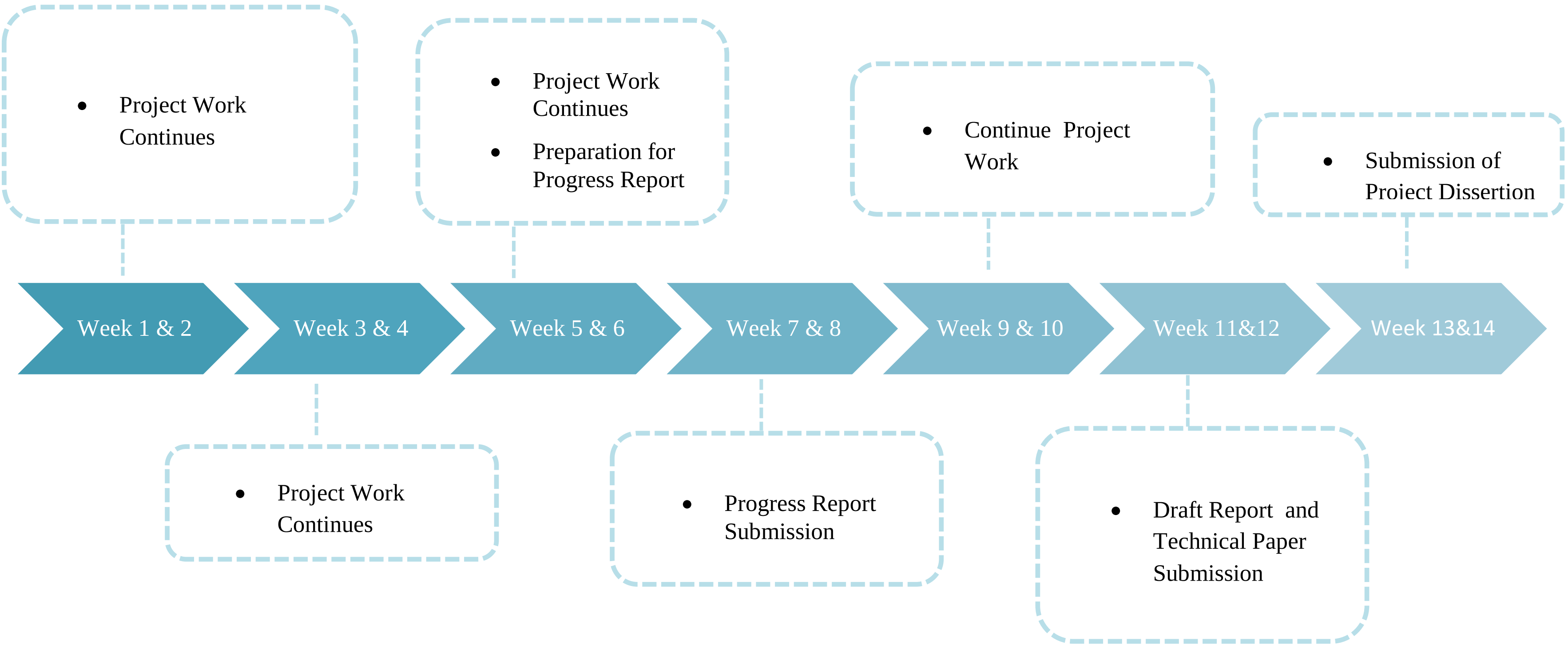
3.3 Project Activities



3.4 Key Milestones for Simulation



3.4 Key Milestones for FYP II



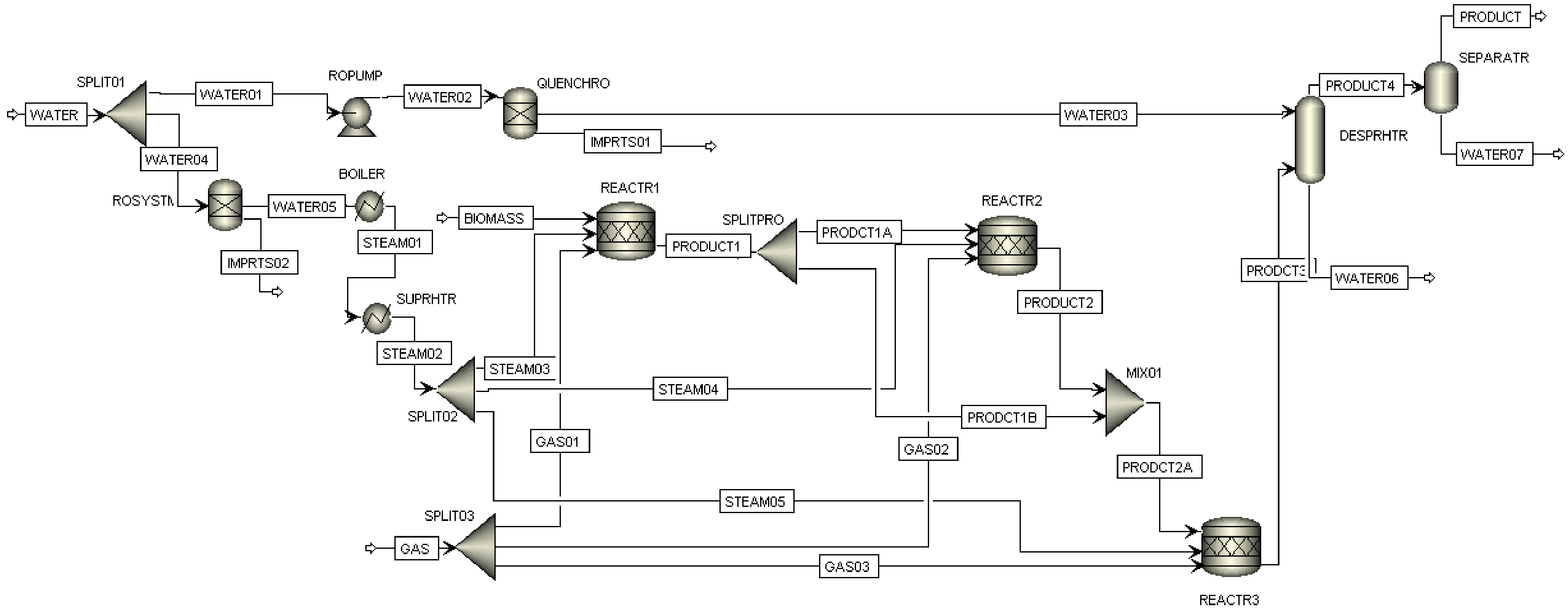
3.5 Gantt chart

No	Week / Detail	1	2	3	4	5	6	7	8	9	10	11	12	13	14	15
1	Project Work Continues															
2	Submission of Progress Report															
3	Project Work Continues															
4	Pre-EDX															
5	Submission of Draft Report															
6	Submission of Dissertation (soft bound)															
7	Submission of Technical Paper															
8	Oral Presentation															
9	Submission of Project Dissertation (Hard Bound)															

CHAPTER 4

4.0 Results and Discussions

4.1 Validation of Model



The previous diagram is the picture of the whole simulation that has been done in Aspen Plus. After simulation is completed, the information of product composition is collected.

Gas Composition	kmol/hr	%	Dry N2 Free
C	0.0000000	0.00%	-
O2	0.0243492	5.81%	-
CO	0.0343996	8.21%	11.86%
CO2	0.0267899	6.40%	9.24%
CH4	0.0098244	2.35%	3.39%
H2	0.2189691	52.29%	75.51%
N2	0.1005572	24.01%	-
H2O	0.0038684	0.92%	-
Total	0.4187577	100.0%	100.00%

Table 4.1: Simulation Result (Dry, N_2 Free)

To validate the model, the gas composition from Aspen Plus is compared with the value from Khan et all, 2014. This paper is also using the exact plant at Block P, UTP. However, this result is based on experiments that they had done.

Gas Composition	% (Dry N2 Free)
CO	9%
CO2	0%
CH4	13%
H2	78%
Total	100%

Table 4.2: Experiments Result (Dry, N_2 Free)

From the results, there is not much difference in percentage of hydrogen percentage. The percentage error of hydrogen production is 3.18% where it is within the acceptable range. The presence of carbon dioxide (CO_2) and low percentage of methane (CH_4) in Aspen Plus's results may be cause from the excluding of solids reaction in the simulation. For next approach)h, solids reaction (production of char and tar) need to be identified and applied in the simulation. Thus, this model of biomass gasification system is accepted and can be used for further research.

4.2 Effect of Gasifier Temperature

Temperature is one of the variables that effect production of hydrogen in fluidized bed gasifier. In this research, the temperature of gasifier is varied from the range of 600 to 750^{o}C. From Figure 4.4, hydrogen content in gas composition increase as the temperature is at the range from 600 to 675^{o}C, however, for carbon monoxide, the production decrease at this temperature range and started to increase after 675^{o}C. This occur due to high reaction occur during the water gas shift reaction (Eq. 4). Less production of carbon dioxide occurred at 600 to 675^{o}C and the amount started to rise at the temperature after 675^{o}C. For methane, low composition at the range of 600 to 675^{o}C is because of low activity of methane steam reforming reaction (Eq. 3). There are some error in prediction the composition of product gas is because of ignoring tar and char production in simulation.

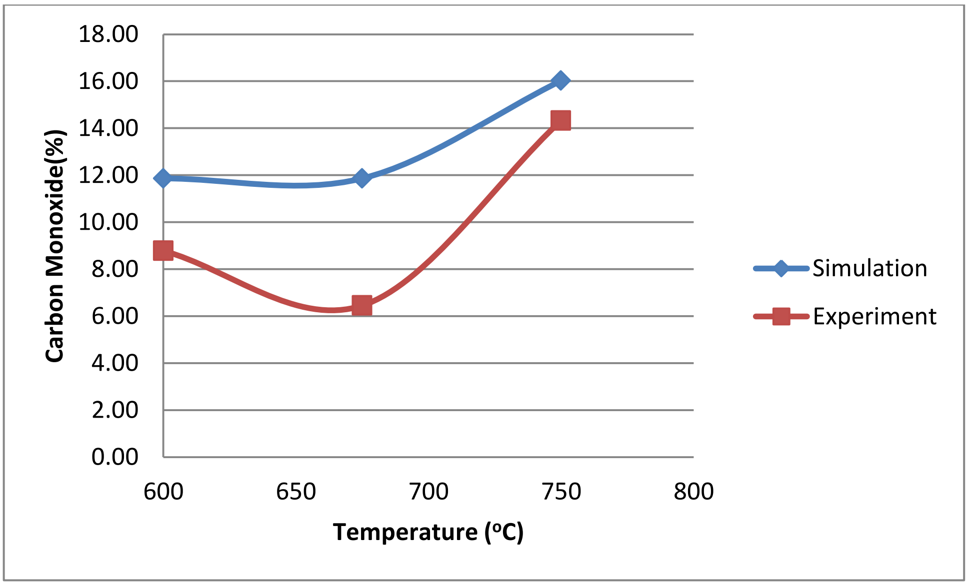


Figure 4.1: Effect of Temperature on Carbon Monoxide

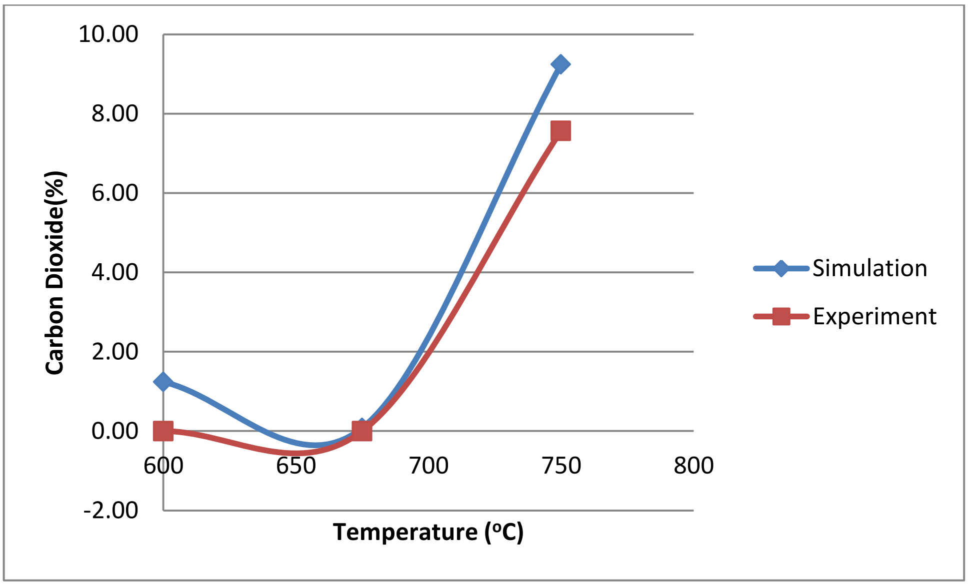


Figure 4.2: Effect of Temperature on Carbon Dioxide

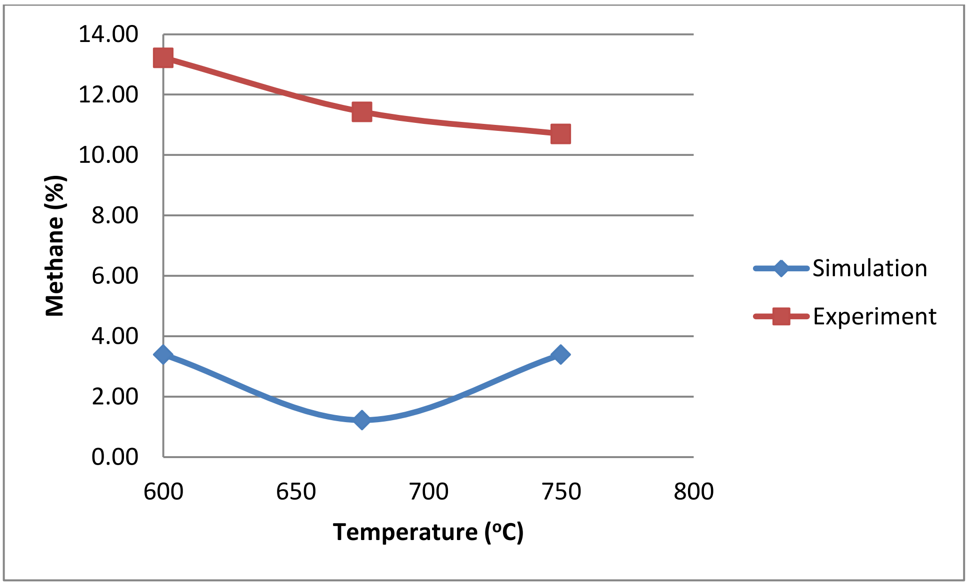


Figure 4.3: Effect of Temperature on Methane

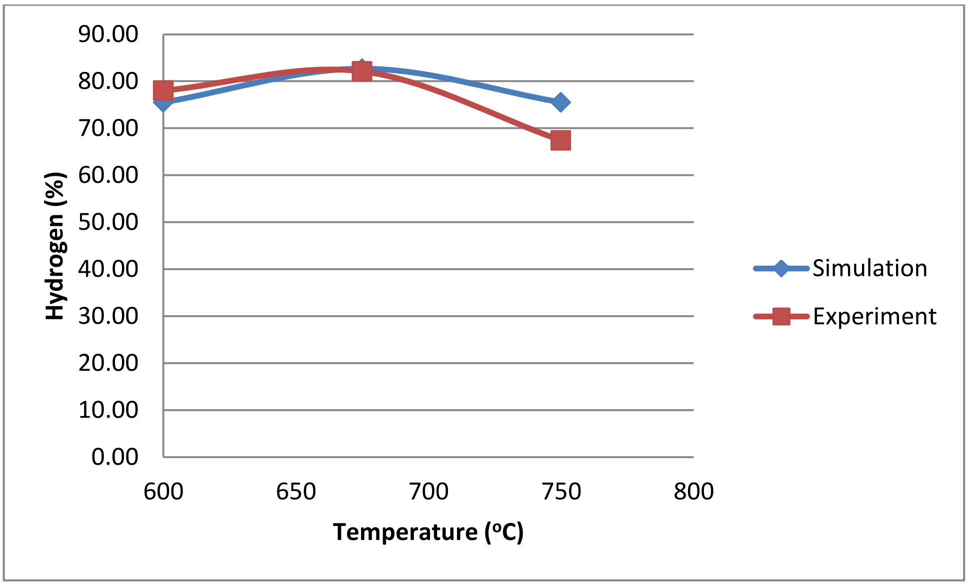


Figure 4.4: Effect of Temperature on Hydrogen

4.3 Effect of Steam to Biomass Ratio (S/B Ratio)

The influence of steam to biomass ratio on hydrogen production has also been studies. The flow rate of biomass is adjusted from 1.8kg/hr to 1.35kg/hr and 1.1kg/hr while the flow rate of steam is maintained at 2.7kg/hr to each each reactor. This will change the steam to biomass ratio from 1.5 to 2 and 2.5. By increasing the S/B ratio, the production of hydrogen is increased from 79.92% to 82.4%. The increment is up to 2.5% of hydrogen production. Besides that, production of methane is also increasing. However, a decrease amount of carbon monoxide is detected when S/B ratio is increase. Reducing in biomass flowrate helps in increasing amount of steam in the process, thus, enhance the reactions of water gas shift and methane reforming reactions. This evidence proved that increasing the S/B can increase composition of hydrogen.

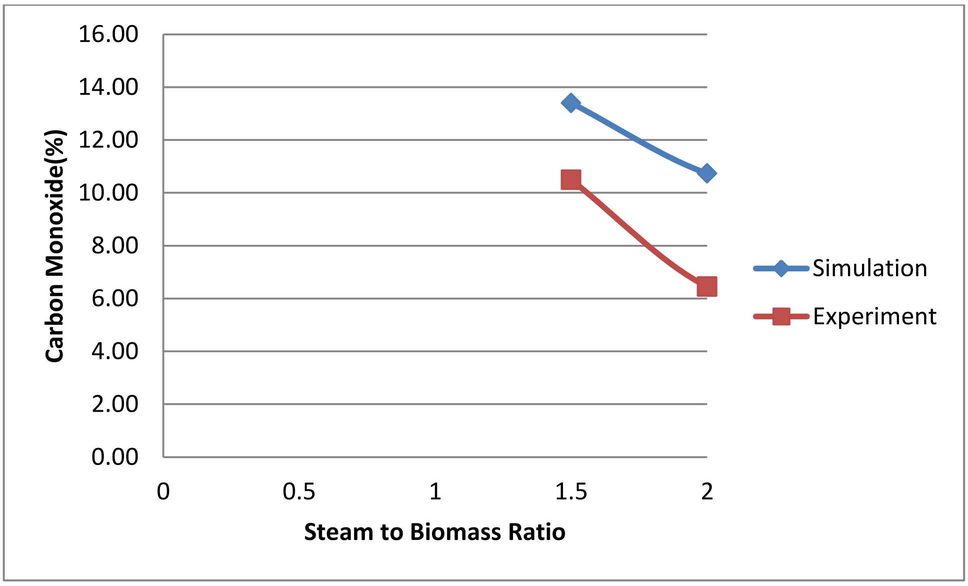


Figure 4.5: Effect of S/B Ratio on Carbon Monoxide

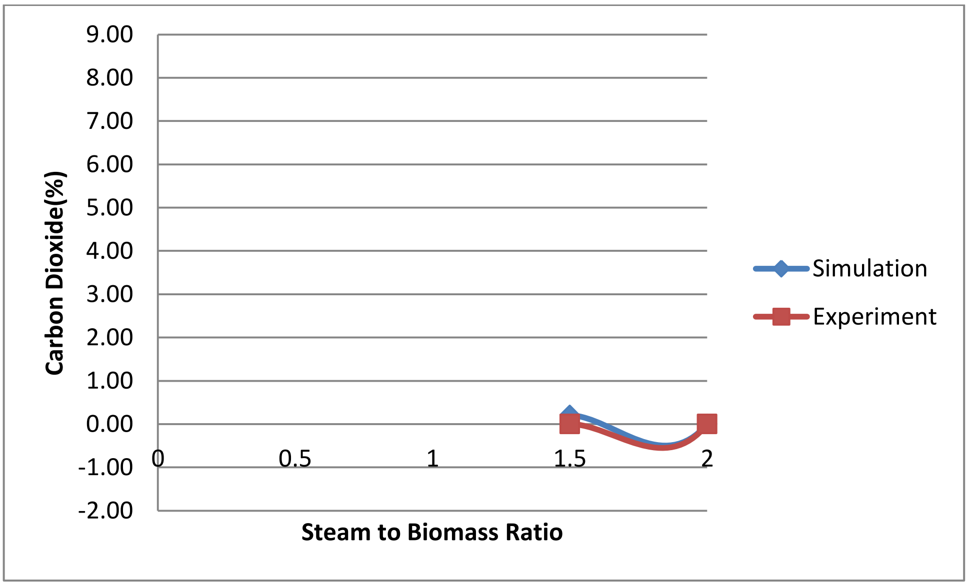


Figure 4.6: Effect of S/B Ratio on Carbon Dioxide

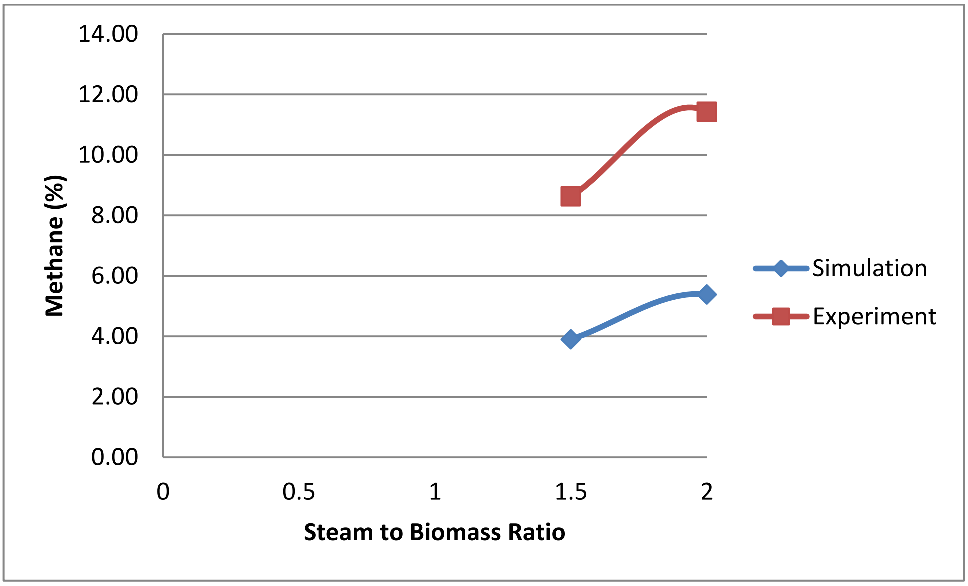


Figure 4.7: Effect of S/B Ratio on Methane

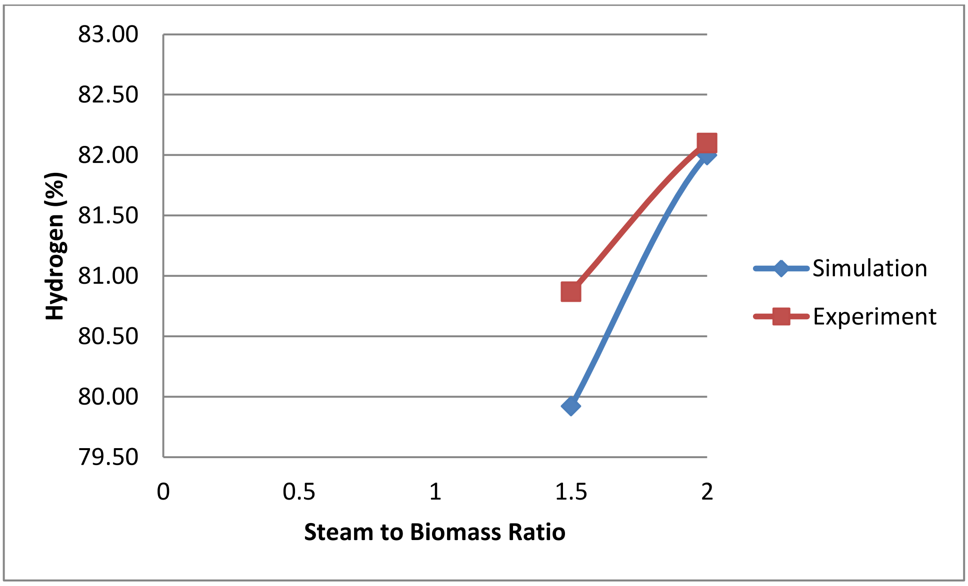


Figure 4.8: Effect of S/B Ratio on Hydrogen

4.3 Problem Encountered

Insufficient Data

There are insufficient data where only a few data point is used to plot graphs for results. For a better comparison results with simulation and experiment, more data points should be used in the graph (simulation and experiment). However, for this research, only three points for temperature variable (600^{o}C, 675 ^{o}C, 700 ^{o}C) and two points for steam to biomass ratio. This lack of data is due to difficulty in obtaining the results from the laboratory itself.

Solids Handling

Besides product gas, tar and char are the solid products of gasification reaction. For this research, the solids product is not included in the simulation. This information can effect on the results of the composition. In the future, solids handling can be included in the simulation itself.

CHAPTER 5

5.0 Conclusion

Biomass is one of the energy sources that can replace fossil fuels. Not only it is a renewable source, biomass gasification system is environmental friendly where it can reduce the emission of carbon dioxide. Biomass gasification system is a system that can convert carbonaceous material into convenient gaseous fuels.

In the plant at Block P, UTP, palm kernel shell is used as feedstock because its ability in producing high amount of hydrogen which is the carrier energy. Currently, there are no model has been done for this plant. This research has achieved in developing biomass gasification system model using Aspen Plus Software.

With using Aspen Plus software as modelling tool, a steady state model of biomass gasification system has completed. The model is validated by comparing the results of simulation with experiment's result and the model is acceptable. There is a slight difference of the result; however, the error of difference is within acceptable range. This error can further reduced by optimize it in the future by including solid handling in the simulation and including exact conversion for each reaction included in the reactor. Thus, the objective of this project is achieved.

Two variables are manipulated in this studies, temperature and steam to biomass ratio. It is found that the hydrogen production favours high temperature, however, the production decrease at 750^{o}C due to reverse carbonation reaction. The optimum temperature for fluidized bed gasifier is 675 ^{o}C where the production of hydrogen is 82.68%. For S/B Ratio, the production of hydrogen increased as the ratio increase. When S/B ratio is at 2.5, the percentage of hydrogen production increase from 79.92% to 82.4%. This shows that hydrogen production favours S/B ratio. The effect of hydrogen production in temperature and steam to biomass ratio has been studied. Thus, this objective is also achieved.

5.1 Recommendation

Information Gathering

There are some difficulties for students to obtain the data from the plant itself as the students are not allowed to enter the plant. This are one of the reason student have difficulties in completing the task. In the future, it would be recommended if can expose students at the plant for convenient in gathering the data they need.

Obtain Good Results

To obtain good results, the conversion factor and information regarding solids product need to obtain through experiments at the plant. It is advisable for student to be included when experiments are conducted for easy asses of information that they need. Furthermore, student will be able to understand more regarding the research that they are handling. Other than that, it would be better if more data point for plotting is used in results graph (simulation and experiment). This is to ensure more accurate comparison can be made from simulation and experiment.

Dynamic Simulation

In the future, dynamic behaviour can be done for this simulation to understand further about this simulation model. By converting steady state model to dynamic state, the gas production can be analysed in a certain time frame. Thus, a better understanding in the process can be achieved.

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