IIT Gandhinagar

CL 425

Project Report (Group-1)

Syngas Production

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1   INTRODUCTION

1.1   Syngas

As the amount of fossil fuels available decreases and the cost of petroleum-based fuels increases, there is a greater need for alternative fuel sources. While methods to produce cleaner, more abundant fuels exist, there is no consensus as to which method holds the maximum promise, resulting in an ongoing debate and a high demand for more efficient processes to generate clean biofuels. One promising process for biofuel production involves the formation of synthesis gas which can then be converted to useful compounds.

Syngas is an abbreviation for synthesis gas, which is a mixture comprising of carbon monoxide, carbon dioxide, Methane and hydrogen. By weight percentage CO is 60% of Syngas, Hydrogen is 30% and rest is CO2 and Methane. The syngas is produced by gasification of a carbon containing fuel to a gaseous product that has some heating value . Major sources of Syngas production are Biomass, natural gas or virtually any hydrocarbon feedstock through steam reforming.

The name syngas is derived from the use as an intermediate in generating synthetic natural gas and to create ammonia or methanol. It is a gas that can be used to synthesize other chemicals, hence the name synthesis gas, which was shortened to syngas. Syngas is also an intermediate in creating synthetic petroleum to use as a lubricant or fuel .

Fuel	Gasification Method	Volume Percentage		Calorific value (MJ/m^3)				
		CO	H2		CH4	CO2	N2	
Charcoal	Downdraft	28-31	5-10		1-2	1-2	55-60	4.60-5.65
Wood with 12-20% moisture content	Downdraft	17-22	16-20		2-3	10-15	50-55	5.00-5.86
Wheat straw pellets	Downdraft	14-17	17-19			11-14		4.5
Coconut husks	Downdraft	16-20	17-19.5			10-15		5.8
Coconut shells	Downdraft	19-24	19-15			11-15		7.2
Pressed Sugarcane	Downdraft	15-18	15-18			12-14		5.3
Charcoal	Updraft	30	30			3.6	46	5.98
Corn cobs	Downdraft	18.6	18.6		6.4			6.29
Rice hulls pelleted	Downdraft	16.1	16.1		0.95			3.25
Cotton stalks cubed	Downdraft	15.7	15.7		3.4			4.32

1.2 Biomass

The rice husk, also called rice hull, is the coating on a seed or grain of rice. It is formed from hard materials, including silica and lignin, to protect the seed during the growing season. Common products from rice husk are: solid fuel (i.e., loose form, briquettes, and pellets), carbonized rice husk produced after burning, and the remaining rice husk ash after combustion. Rice husk in its loose form is mostly used for energy production, such as combustion and gasification. Gasification is the process of converting rice husk to synthesis gas (syngas) in a gasifier reactor with a controlled amount of air. Syngas can be used as fuel for drying and cooking or in a cogeneration system to produce electricity.

1.3 Characteristics of Rice Husk

Average properties of Rice Husk in Proximate and Ultimate analysis are shown in following table.

Proximate Analysis	(% weight)
Moisture	6.47
Volatile Matter	60.3
Fixed Carbon	28
Ash	11.7

Ultimate Analysis (dry ash free, % weight)	
C	42.99
H	6.15
N	0.33
O	38.33

1.4 Gasification

Gasification is a process in which combustible materials are partially oxidized or partially combusted. The product of gasification is a combustible synthesis gas, or

syngas. Because gasification involves the partial, rather than complete, oxidization of the feed, gasification processes operate in an oxygen-lean environment. Just as most combustion-based processes such as power plants operate with excess oxygen to ensure complete conversion of the fuel, gasification processes also typically operate above their stoichiometric oxygen-to-fuel ratio to ensure near complete conversion to syngas. The amount of oxygen used in gasification, however, is always far less than that used in combustion and typically is less than half. Biomass gasification consists in the decomposition of a solid, for example wood, by a reactive gas, for example air, to obtain a gaseous fuel. During this process, biomass is subjected to four successive thermochemical phenomena: drying, pyrolysis, oxidation and reduction.

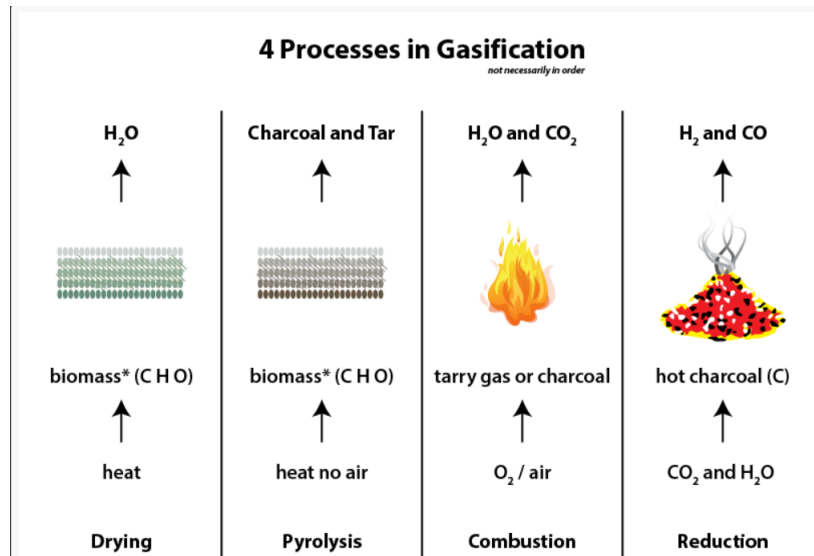*Figure 1: Image source http://www.ankurscientific.com/technology.html*

1.5 Four Stage of Gasification

1.5.1 Drying

The feed moisture is removed by evaporation. This is an endothermic process, it occurs at a temperature between 100 °C and 160 °C.

1.5.2 Pyrolysis

As the temperature of the solid increases, gases are generated by dry biomass from 250 °C. These gases are constituted of non-condensable species (methane, hydrogen, carbon monoxide, carbon dioxide) and condensable vapours (tar). The solid residue from this operation is called coke and contains carbon and mineral materials.

1.5.3 Oxidation

Oxidation occurs in the presence of a reactive gas (air, steam, pure oxygen, hydrogen) which condition the calorific value of the gas leaving the gasifier. The use of air as reactive gas is the more common. Oxidation is the phase that provides heat for the three phases of the gasification process.

1.5.4 Reduction

The coke reacts with water vapour and carbon dioxide, thereby forming hydrogen and carbon monoxide, principal constituents of the combustible gas produced.

1.6 Gasification Reactions

1. $C + 0.5O_2 \rightarrow CO$ $\Delta H_R^\circ = -111 MJ/Kmol$ (Char Partial Combustion)

2. $CO + 0.5O_2 \rightarrow CO_2$ $\Delta H_R^\circ = -283 MJ/Kmol$ (CO Partial Combustion)

3. $H_2 + 0.5O_2 \rightarrow H_2O$ $\Delta H_R^\circ = -242 MJ/Kmol$ (H_2 Partial Combustion)

4. $C + CO_2 \leftrightarrow 2CO$ $\Delta H_R^\circ = +172 MJ/Kmol$ (Boudouard Reaction)

5. $C + H_2O \leftrightarrow CO + H_2$ $\Delta H_R^\circ = +131 MJ/Kmol$ (Water-Gas)

6. $CO + H_2O \leftrightarrow CO_2 + H_2$ $\Delta H_R^\circ = -41 MJ/Kmol$ (Water-Gas Shift)

7. $CH_4 + H_2O \leftrightarrow CO + 3H_2$ $\Delta H_R^\circ = +206 MJ/Kmol$ (Steam-Methane reforming)

8. $CH_4 + 2H_2O \leftrightarrow CO + 4H_2$ $\Delta H_R^\circ = +165 MJ/Kmol$ (Steam-Methane reforming)

1.7 Gasifier

The Gasifier unit is essentially a chemical reactor, where several thermo-chemical processes such as pyrolysis, combustion, and reduction take place.

1.8 Types Of Gasifier

Gasifiers can be classified based on the density factor, which is a ratio of the solid matter (the dense phase) a gasifier can burn to the total volume available. Gasifiers can be (a) dense phase reactors, or (b) lean phase reactors.

1.8.1 Dense phase reactors

In dense phase reactors, the feedstock fills most of the space in the reactor. They are common, available in different designs depending upon the operating conditions, and are of three types: downdraft, updraft, and cross-draft.

1.8.2 Downdraft or co-current gasifiers
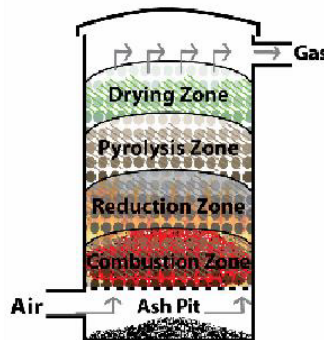
The downdraft (also known as co-current) gasifier is the most common type of gasifier. In downdraft gasifiers, the pyrolysis zone is above the combustion zone and the reduction zone is below the combustion zone. Fuel is fed from the top. The flow of air and gas is downwards (hence the name) through the combustion and reduction zones. The term co-current is used because air moves in the same direction as that of fuel, downwards. A downdraft gasifier is so designed that tar, which is produced in the pyrolysis zone, travels through the combustion zone, where it is broken down

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or burnt. As a result, the mixture of gases in the exit stream is relatively clean. The position of the combustion zone is thus a critical element in the downdraft gasifier, its main advantage being that it produces gas with low tar content, which is suitable for gas engines.

1.8.3 Updraft or counter-current gasifier
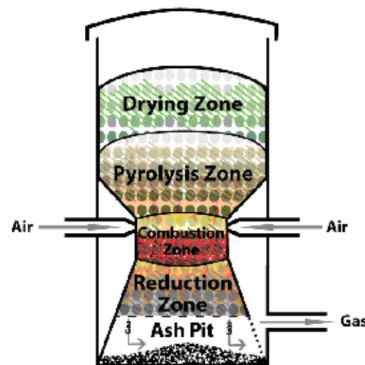
In updraft gasifiers (also known as counter-current), air enters from below the grate and flows upwards, whereas the fuel flows downwards. An updraft gasifier has distinctly defined zones for partial combustion, reduction, pyrolysis, and drying. The gas produced in the reduction zone leaves the gasifier reactor together with the products of pyrolysis from the pyrolysis zone and steam from the drying zone. The resulting combustible producer gas is rich in hydrocarbons (tars) and, therefore, has a higher calorific value, which makes updraft gasifiers more suitable where heat is needed, for example in industrial furnaces. The producer gas needs to be thoroughly cleaned if it is to be used for generating electricity.

1.8.4 Cross-draft gasifier
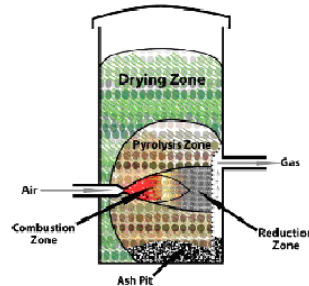
In a cross-draft gasifier, air enters from one side of the gasifier reactor and leaves from the other. Cross-draft gasifiers have a few distinct advantages such as compact construction and low cleaning requirements. Also, cross-draft gasifiers do not need a grate; the ash falls to the bottom and does not come in the way of normal operation.

1.8.5 Lean phase reactors

Lean phase gasifiers lack separate zones for different reactions. All reactions – drying, combustion, pyrolysis, and reduction – occur in one large reactor chamber. Lean phase reactors are mostly of two types, fluidized bed gasifiers and entrained-flow gasifiers.

1.8.6 Fluidized bed gasifiers
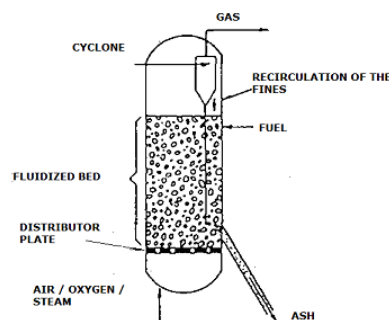
In fluidized bed gasifiers, the biomass is brought into an inert bed of fluidized material (e.g. sand, char, etc.). The fuel is fed into the fluidized system either above-bed or directly into the bed, depending upon the size and density of the fuel and how

it is affected by the bed velocities. During normal operation, the bed media is maintained at a temperature between 550 °C and 1000 °C. When the fuel is introduced under such temperature conditions, its drying and pyrolyzing reactions proceed rapidly, driving off all gaseous portions of the fuel at relatively low temperatures. The remaining char is oxidized within the bed to provide the heat source for the drying and devolatilizing reactions to continue. Fluidized bed gasifiers are better than dense phase reactors in that they produce more heat in short time due to the abrasion phenomenon between inert bed material and biomass, giving a uniformly high (800–1000 °C) bed temperature. A fluidized bed gasifier works as a hot bed of sand particles agitated constantly by air. Air is distributed through nozzles located at the bottom of the feed.

1.8.7 Entrained-flow gasifiers
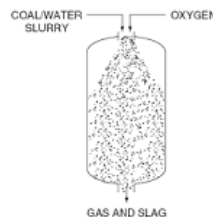
In entrained-flow gasifiers, fuel and air are introduced from the top of the reactor, and fuel is carried by the air in the reactor. The operating temperatures are 1200–1600 °C and the pressure is 20–80 bar. Entrained-flow gasifiers can be used for any type of fuel so long as it is dry (low moisture) and has low ash content. Due to the short residence time (0.5–4.0 seconds), high temperatures are required for such gasifiers. The advantage of entrained-flow gasifiers is that the gas contains very little tar.

1.9 Advantages and disadvantages of different gasifier types

GASIFIER TYPE	ADVANTAGES	DISADVANTAGES
UPDRAFT	Simple Design	High amount of tar and pyrolysis products
	High charcoal burn-out	Extensive gas cleaning required if used for power application
	High fuel to gas conversion efficiency	
	Accepts fuels with higher moisture content	
	Accepts fuels of different sizes	
DOWNDRAFT	Low tar	Limited scale-up
	Best option for usage in gas engines	At low temperatures, more tar produced
	At lower loads, fewer particles in the gas	High amounts of ash and dust
		Fuel requirements are strict
CROSS-DRAFT	Applicable for small-scale operations	High amount of tar produced
	Due to high temperatures, gas cleaning requirements are low	
FLUIDIZED BED	Compact construction	Gas stream contains fine particles of dust
	Uniform temperature profile	Complex system due to low biomass hold up in the fuel bed
	Accepts fuel size variation	Variety of biomass can be used but fuel flexibility is applicable for biomass of 0.1 cm to 1 cm size
	High ash melting point of biomass does not lead to clinker formation	
ENTRAINED-FLOW	Applicable to large systems	High investment
	Short residence time for biomass	Strict fuel requirements

2 SYNGAS: SOLUTION TO ELECTRICITY PRODUCTION SHORTAGE

Table 1: Total Installed Power capacity of India

Fuel	MW	% of Total
Total Thermal	2,21,768	64.10%
Coal	1,95,993	56.60%
Gas	24,937	7.20%
Oil	838	0.20%
Hydro (Renewable)	45,487	13.10%
Nuclear	6,780	2.00%
RES* (MNRE)	72,013	20.80%
Total	3,46,048	

Table 2: The power supply position in the country during 2009-10 to 2018-19

Year	Energy				Peak			
	Requirement	Availability	Surplus (+)/Deficits (-)		Peak Demand	Peak Met	Surplus (+)/Deficits (-)	
	(MU)	(MU)	(MU)	(%)	(MW)	(MW)	(MW)	(%)
2009-10	8,30,594	7,46,644	-83,950	-10.1	1,19,166	1,04,009	-15,157	-12.7
2010-11	8,61,591	7,88,355	-73,236	-8.5	1,22,287	1,10,256	-12,031	-9.8
2011-12	9,37,199	8,57,886	-79,313	-8.5	1,30,006	1,16,191	-13,815	-10.6
2012-13	9,95,557	9,08,652	-86,905	-8.7	1,35,453	1,23,294	-12,159	-9
2013-14	10,02,257	9,59,829	-42,428	-4.2	1,35,918	1,29,815	-6,103	-4.5
2014-15	10,68,923	10,30,785	-38,138	-3.6	1,48,166	1,41,160	-7,006	-4.7
2015-16	11,14,408	10,90,850	-23,558	-2.1	1,53,366	1,48,463	-4,903	-3.2
2016-17	11,42,929	11,35,334	-7,595	-0.7	1,59,542	1,56,934	-2,608	-1.6
2017-18	12,12,134	12,03,567	-8,567	-0.7	1,64,066	1,60,752	-3,314	-2
2018-19*	7,69,399	7,64,627	-4,773	-0.6	1,77,022	1,75,528	-1,494	-0.8

The above table and diagrams just give a picturesque of energy/electricity production of India. From the above data one can claim that India is very much dependent on Coal for producing of electricity which constitutes 57% of total production. But the major concern is the fast depleting Coal Reserves. According to Greenpeace in its report said that Coal India (CIL)'s reserves are fast depleting. It said CIL is left with just 18.2 billion tonnes of extractable coal, according to the United Nations reserve classification system.

Even these reserves would exhaust in about 17 years, it added . The second table gives the energy requirement of India and the availability of Energy. From the data mentioned above, even now we are not able to fulfil our energy requirements which then affect the citizens of India. Hence it is the need of the hour to search for potential source of electricity production. Also, it will increase the self-sufficiency in producing electricity as today around 1.5 MW of electricity is being imported from Bhutan. Thus, we need to search an alternative for the electricity production and shifting to Renewable source to produce electricity is the best option we have today.

Electricity Generation From Renewable (source wise)
April-December, 2016   vis-à-vis   April-December, 2015

All Figure in MU

Source-Wise All India Generation from Renwables	For the Month of		Commulative for the period	
	Dec., 2016	Dec ., 2015	Apr., 2016 to Dec., 2016	Apr., 2015 to Dec.,2015
Wind	1779.89	1498.01	38851.46	28430.65
Solar	1157.9	662.04	9378.35	5181.10
Biomass	333.48	355.56	3072.17	2685.71
Bagasse	1781.57	1912.04	5852.12	7610.61
Small Hydro	339.19	528.56	6898.45	7035.77
Others	50.51	19.6	285.77	197.98
Total	5442.54	4975.81	64338.32	51141.82

Figure 2: Image source: Exec-summary for Month of Jan,2017 by Govt. of India

Area, production and yield of major Crops

Crops	Area (Lakh hectare)			Production (Million Tonnes)			Yield (kg/hectare)		
	2013-14	2014-15	2015-16*	2013-14	2014-15	2015-16*	2013-14	2014-15	2015-16*
Rice	441.36	441.10	433.88	106.65	105.48	104.32	2416	2391	2404
Wheat	304.73	314.65	302.27	95.85	86.52	93.50	3145	2750	3093
Coarse cereals	252.19	251.70	237.75	43.29	42.86	37.93	1717	1703	1596
Pulses	252.12	235.54	252.59	19.25	17.15	16.47	764	728	652
Foodgrains	1250.41	1243.00	1226.50	265.04	252.02	252.22	2120	2028	2056
Oilseeds	280.50	255.96	261.34	32.74	27.51	25.30	1168	1075	968
Sugarcane	49.93	50.66	49.53	352.14	362.33	352.16	70522	71512	71095
Cotton@	119.60	128.19	118.72	35.90	34.80	30.15	510	462	432
Jute & Mesta#	8.38	8.09	7.85	11.69	11.12	10.47	2512	2473	2399

* 4th advance estimates @ Production in million bales of 170 kg each.
# Production in million bales 180 Kg. each.

Figure 3: Image source-Annual Report by Department of Agriculture, India

The above data provides the different types of renewable energy sources and the quantity of electricity produced from them. Biomass constitutes the least electricity production resource, but this quantity can be improved further because of the raw materials are available quite cheaply. Syngas can be a potential source of producing electricity in nearby future because the raw materials are available cheaply and easily. Also, India is the second largest rice producing nation in the world producing over 100 million Tons of rice annually . This shows electricity production through biomass has a great future in India.

The cultivation of rice results in two major types of residues – Straw and Husk –having attractive potential in terms of energy. Although the technology for rice husk utilization is well-proven in industrialized countries of Europe and North America,

such technologies are yet to be introduced in the developing world on commercial scale. The importance of Rice Husk and Rice Straw as an attractive source of energy can be gauged from the following statistics:

Rice Straw

- 1 ton of Rice paddy produces 290 kg Rice Straw

- 290 kg Rice Straw can produce 100 kWh of power

- Calorific value = 2400 kcal/kg

Rice Husk

- 1 ton of Rice paddy produces 220 kg Rice Husk

- 1-ton Rice Husk is equivalent to 410- 570 kWh electricity

- Calorific value = 3000 kcal/kg

- Moisture content = $5 - 12\%$

Rice husk can be used for power generation through either the steam or gasification route. For small scale power generation, the gasification route has attracted more attention as a small steam power plant is very inefficient and is very difficult to maintain due to the presence of a boiler. In addition, for rice mills with diesel engines, the gas produced from rice husk can be used in the existing engine in a dual fuel operation.

The benefits of using rice husk technology are numerous. Primarily, it provides electricity and serves to dispose of agricultural waste. In addition, steam, a by-product of power generation, can be used for paddy drying applications, thereby increasing local incomes and reducing the need to import fossil fuels. Rice husk ash, the by-product of rice husk power plants, can be used in the cement and steel industries further decreasing the need to import these materials.

3 PROCESS DESCRIPTION

3.1 Process Involved

- Biomass preparation

- Biomass drying

- Gasification

- Gas purification

- Gas cooling

- Syngas separation

3.2 Biomass Separation

Rice husk contains some impurities like dust and unnecessary materials that must be removed before introducing it into drying process. This can be done by using specific sieves. In our simulation we use pure rice husk.

3.3 Biomass Drying

Drying is the process in which moisture is removed. Rice husk contains some moisture so it is necessary to remove moisture contents. There are various types of dryer available for drying like fluidized bed dryer, rotary dryer and rolling bed dryer. In our process we use rotary dryer. It removes moisture from materials by bringing it to direct contact to heated gas. Rolling bed dryer can be used as well. For our simulation, RSTOIC is used. Dry gas is used to remove moisture.

3.4 gasification

Generally fluidized bed gasifier is used for gasification of rice husk. For simulation, it is done in three steps.

- Pyrolysis: RYIELD (R-102) is used for pyrolysis process. It decomposed non-conventional components into conventional components (Hydrogen, Nitrogen,

Carbon, Sulphur, Oxygen)

- Combustion: RGIBS (R-103) is used for combustion

- Gasification: RGIBS (R-104) is used for gasification. Since we do not know the reaction pathways and kinetics constants for the reaction taking place in gasifier so it is preferred to use RBIBS to predict equilibrium composition of Syngas.

All three processes, described above are take place in gasification section. For ASPEN simulation model we use three different block to show three different processes.

3.5   Gas Purification

After the gasification process Syngas should be purified. Syngas contains ash, unused rice husk water. Cyclone is used to remove solid particles (ash). In ASPEN simulation, Flash (V-102) is used to remove water contents. For industrial purpose knock out filter is used.

3.6   Gas Cooling

Syngas is at high temperature after leaving gasifier (about 700°C-800°C) so it necessary to remove excess heat from it. It can be done using heat exchanger (generally shell and tube heat exchanger is preferred). Water can be used as coolant. It is cheap and steam formed from cooling process can be used other purposes.

3.7   Gas Separation

Nitrogen Separation is important after Syngas production as it is inert and takes lot of volume in storage. Separator (S-102) is used to separate Syngas. In industries, Adsorption based technologies are used for Nitrogen separation with high efficiency. The adsorption gas separation process in nitrogen separators is based on the phenomenon of fixing various gas mixture components by a solid substance called an adsorbent.
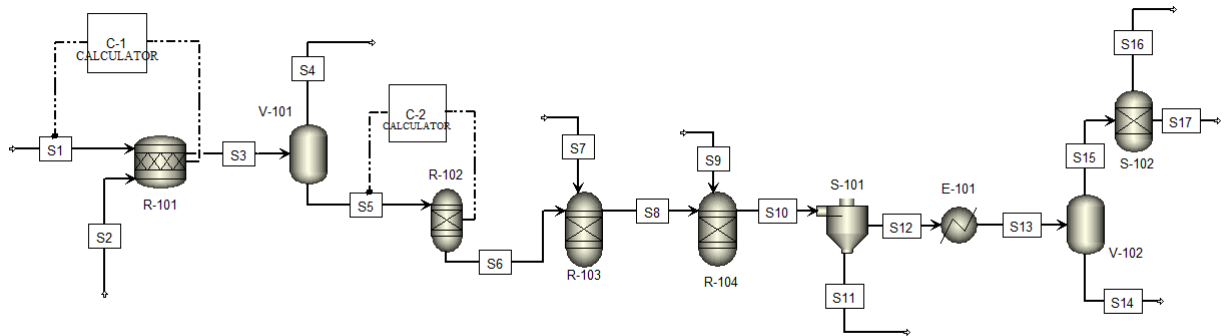
4 SIMULATION

4.1 Flowsheet

Figure 4: Flowheet of Aspen Plus Simulation

4.2 Assumptions

The simulation of the described method is done in Aspen Plus. The simulation is based on the minimization of Gibbs energy at equilibrium and is developed under the following assumptions

- The process is in steady state

- Drying of rice husk is instantaneous

- All reactions are in equilibrium

- Reactor blocks are operating in isothermal conditions

- The sulphur and chlorine contents in Rice husk are neglected

- Ash is inert and do not participate in reactions

Gasification process is simulated by the combination of different unit operation blocks.

4.3 Non-Conventional method for drying and burning Rice husk

Rice Husk cannot be entered as a conventional input in ASPEN Plus. Rice Husk is a heterogenous solid that do not participate in chemical or phase equilibrium. In Aspen such solids are added as a non-conventional input.

We must define the enthalpy and density of unconventional input Rice Husk. In this simulation, we used HCOLAGEN and the DCOLIGT models to calculate the enthalpy and density of coal. Aspen Plus uses component attributes to represent nonconventional components in terms of a set of identifiable constituents needed to calculate physical properties. HCOALGEN uses the proximate analysis, ultimate analysis, and sulphur analysis to calculate the enthalpy of coal.
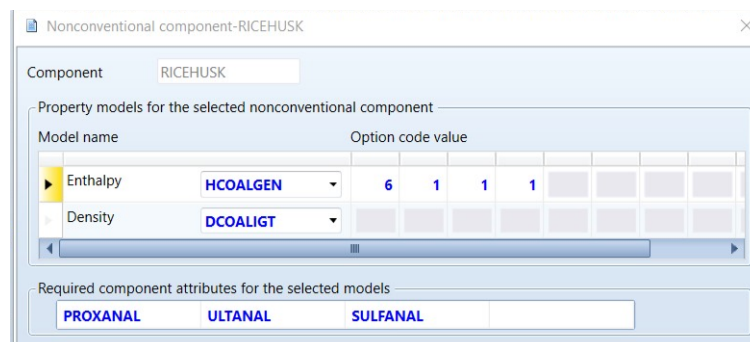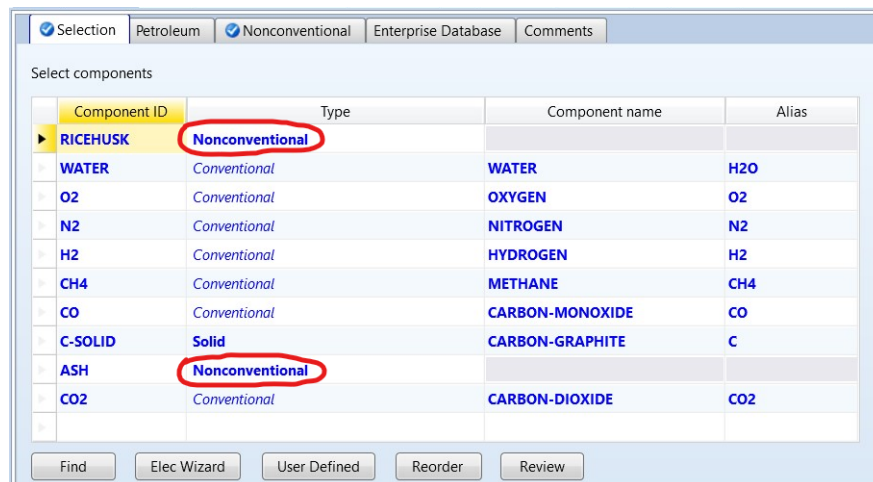
Similarly, ASH is defined as a non-conventional input in this simulation with HCOAL-GEN and DCOLIGT property models. For this simulation, Proximate and Ultimate

analysis data of Rice Husk is taken from a reliable source (Exact composition is mentioned in the Introduction of this report)

4.4 Block Descriptions

4.4.1 Drier (R-101)

Block type: Rstoic

The crumpled Rice Husk contains large amount of water (6.47%). Rstoic is used for the predrying process. Some part of fed wet rice husk is converted into water, reducing the moisture content to 1.5% by weight. The moisture content of dried Rice husk is specified in the calculator block C-1 which calculates the conversion of Rice husk to water by running FORTRAN statements.

Specifications:

Figure 5: Defined Specifications
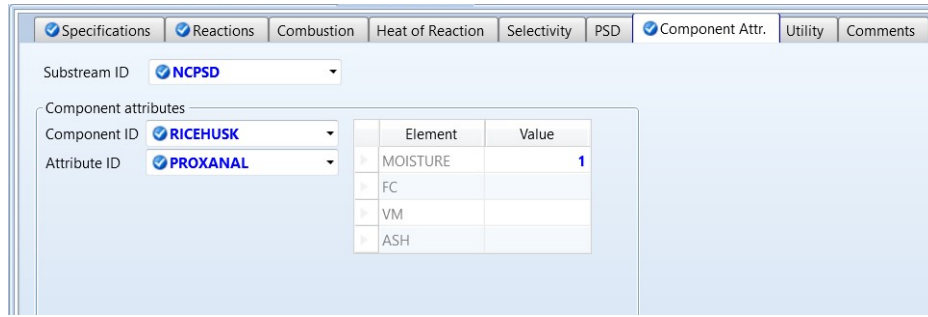

Figure 6: Defined reactions

Figure 7: Defined Component Attributes

4.4.2 Flash Column (V-101)

Block type: Flash2

Since the Rstoic block contains only one outlet stream. A flash2 block is used to model the removal of water and Nitrogen gas from the dried husk. Water and air leaves the system (S4). Rice husk with reduced moisture content (S5) goes to the R-Yield block.
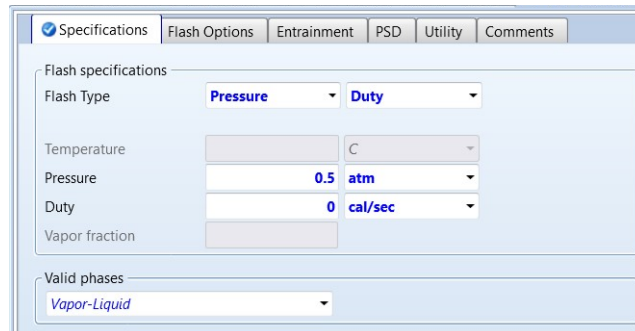

Figure 8: Block Setup

4.4.3 Devolatizer (R-102)

Block type: R-Yield

R-Yield is introduced in the flowsheet to model complete drying and devolatization of the Rice Husk. This process converted all the volatile components defined in proximate analysis to individual species of Carbon, Nitrogen, hydrogen, Oxygen, Water and Ash. The yield distribution is calculated by the calculator block C-2

according to defined ultimate analysis of the Rice Husk. It converts non-conventional Rice Husk into conventional components.

Figure 9: Defined Specifications

Figure 10: Defined Yield

Component Yield defined here acted like dummy variables. Later these values were overridden by Calculator block C-2 in accordance with the Fortran Statements (based on the ultimate analysis of Rice Husk). Ash is defined here as a non-conventional input with 100% ASH content in the proximate analysis.

Figure 11: Defined Component Attributes

4.4.4 Gasifier (R-103 and R-104)

Block type: RGibbs (both)

Block R-103 is a Gibbs free energy reactor introduced in the flowsheet to simulate combustion (partial and full). The defined conventional products in this reactor are N2, H2, CO, CO2 and C-SOLID.

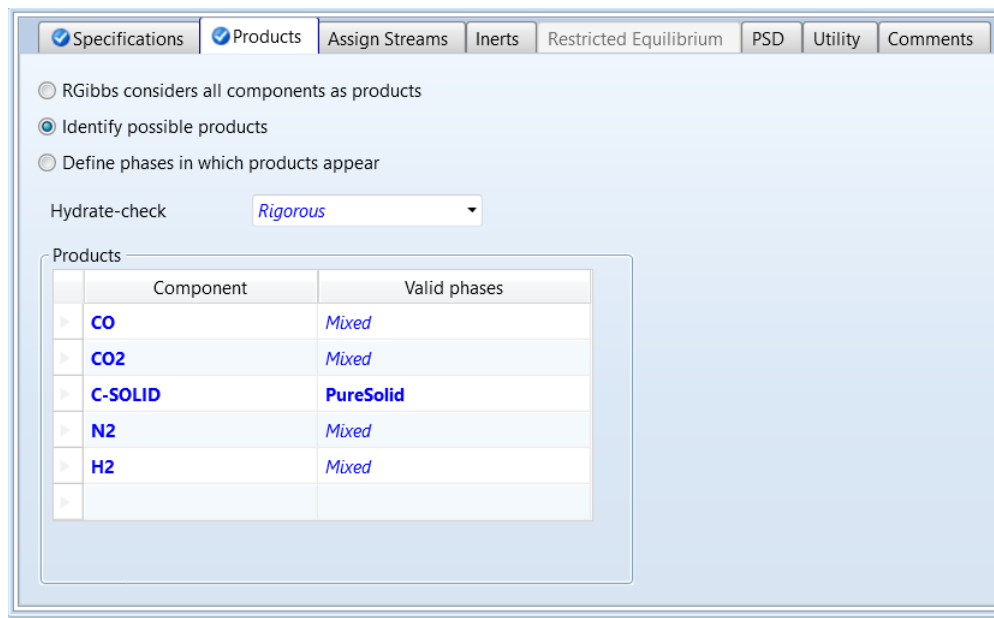

Figure 12: Defined Specifications

Figure 13: Defined Products

Heated Air (S7) enters the system via this block. It is required for the combustion. The combustion and gasification temperature ranges from 500-1000. These blocks are kept at an isothermal temperature of 900 °C. A sensitivity analysis is done to figure out the optimal temperature (discussed in the later section).

In RGibbs block R-104 gasification takes place. Heated Steam (S9) at high pressure enters the block and gasifies the products from R-103. Water-gas and water-gas shift reaction takes place in this reactor to form CO, CO2 and H2.

Figure 14: Defined Specifications

Figure 15: Defined Products

4.4.5 Cyclone Separator (S-101)

Block type: SSplit

This block is used to model ASH removal from the system. Stream S10 given as a feed to the block, it separates out the ASH (S11) with the rest of the gases (S12).

Figure 16: Defined Specifications

Figure 17: Defined Specifications

4.4.6   Heat exchanger (E-101)

Block type: Heater

Stream S12 coming out of Cyclone separator is at a very high temperature. Heater block is used to cooldown the stream to 20 °C. This is done so that water content in the stream S12 becomes liquid and separates easily from the gases through a flash column (V-102).

Figure 18: Defined Specifications

4.4.7   Flash Separator (V-102)

Block type: flash2

This block is used to separate liquid water(S14) from the gases(S15).

Figure 19: Defined Specifications

4.4.8   Separator (S-102)

Block type: Sep

This separator is used to remove Nitrogen present in the dried gases (S15).

Figure 20: Defined Specifications

4.5   Sensitivity Analysis

Temperature inside Gasifier R-104 was varied from 500-1000 °C to check the composition of Syngas produced at different temperatures.
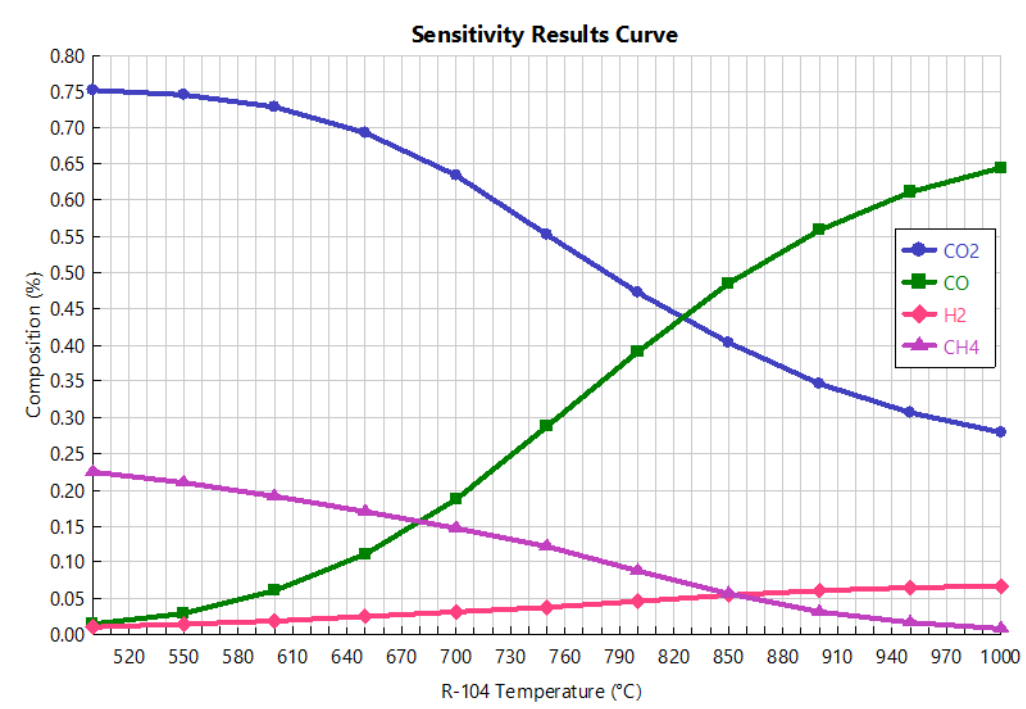
Figure 21: Result Curve

From the above plot of composition vs temperature, the composition of CO and H2 increases with increase in temperature inside gasifier. While the composition of CH4 and CO2 decreases. We achieve favourable composition at high temperatures.

Therefore, we must operate the gasifier at a very high temperature. Preferably at a temperature higher than 850 °C.

4.6 Stream Results

Units		S1	S2	S3	S4
From				R-101	V-101
To		R-101	R-101	V-101	
Stream Class		MCINCPSD	MCINCPSD	MCINCPSD	MCINCPSD
Total Stream					
Temperature	C	25.00	100.00	25.00	24.91
Pressure	bar	1.01	1.01	1.01	0.51
Mass Vapor Fraction		0.00	1.00	0.86	1.00
Mass Liquid Fraction		0.00	0.00	0.00	0.00
Mass Solid Fraction		1.00	0.00	0.14	0.00
Mass Enthalpy	cal/gm	-3991.65	18.62	-565.90	-26.54
Mass Density	gm/cc	1.31	0.00	0.00	0.00
Enthalpy Flow	cal/sec	-1108793.03	31037.82	-1100293.45	-44609.80
Mass Flows	kg/hr	1000.00	6000.00	6999.54	6049.99
RICEHUSK	kg/hr	1000.00	0.00	949.54	0.00
WATER	kg/hr	0.00	0.00	49.99	49.99
O2	kg/hr	0.00	0.00	0.00	0.00
N2	kg/hr	0.00	6000.00	6000.00	6000.00
H2	kg/hr	0.00	0.00	0.00	0.00
CH4	kg/hr	0.00	0.00	0.00	0.00
CO	kg/hr	0.00	0.00	0.00	0.00
C-SOLID	kg/hr	0.00	0.00	0.00	0.00
ASH	kg/hr	0.00	0.00	0.00	0.00
CO2	kg/hr	0.00	0.00	0.00	0.00
Volume Flow	l/min	12.70	109352.50	88479.84	176877.33

Units		S5	S6	S7	S8
From		V-101	R-102		R-103
To		R-102	R-103	R-103	R-104
Stream Class		MCINCPSD	MCINCPSD	MCINCPSD	MCINCPSD
Total Stream					
Temperature	C	24.91	25.00	150.00	900.00
Pressure	bar	0.51	1.01	1.01	1.01
Mass Vapor Fraction		0.00	0.39	1.00	0.94
Mass Liquid Fraction		0.00	0.15	0.00	0.00
Mass Solid Fraction		1.00	0.46	0.00	0.06
Mass Enthalpy	cal/gm	-4002.41	-658.29	30.40	-450.95
Mass Density	gm/cc	1.31	0.00	0.00	0.00
Enthalpy Flow	cal/sec	-1055683.65	-173631.66	4222.33	-181576.15
Mass Flows	kg/hr	949.54	949.54	500.00	1449.54
RICEHUSK	kg/hr	949.54	0.00	0.00	0.00
WATER	kg/hr	0.00	160.93	0.00	0.00
O2	kg/hr	0.00	303.79	105.00	0.00
N2	kg/hr	0.00	2.62	395.00	397.62
H2	kg/hr	0.00	48.74	0.00	66.75
CH4	kg/hr	0.00	0.00	0.00	0.00
CO	kg/hr	0.00	0.00	0.00	623.30
C-SOLID	kg/hr	0.00	340.73	0.00	0.00
ASH	kg/hr	0.00	92.73	0.00	92.73
CO2	kg/hr	0.00	0.00	0.00	269.14
Volume Flow	l/min	12.06	14108.30	10063.64	121442.12

Units		S9	S10	S11	S12
From			R-104	S-101	S-101
To		R-104	S-101		E-101
Stream Class		MCINCPSD	MCINCPSD	MCINCPSD	MCINCPSD
Total Stream					
Temperature	C	100.00	900.00	900.00	900.00
Pressure	bar	3.00	25.33	25.33	25.33
Mass Vapor Fraction		0.00	0.95	0.00	1.00
Mass Liquid Fraction		1.00	0.00	0.00	0.00
Mass Solid Fraction		0.00	0.05	1.00	0.00
Mass Enthalpy	cal/gm	-3743.25	-857.28	22.21	-908.03
Mass Density	gm/cc	0.71	0.01	3.49	0.00
Enthalpy Flow	cal/sec	-259947.84	-404716.15	572.13	-405288.28
Mass Flows	kg/hr	250.00	1699.54	92.73	1606.81
RICEHUSK	kg/hr	0.00	0.00	0.00	0.00
WATER	kg/hr	250.00	259.02	0.00	259.02
O2	kg/hr	0.00	0.00	0.00	0.00
N2	kg/hr	0.00	397.62	0.00	397.62
H2	kg/hr	0.00	58.12	0.00	58.12
CH4	kg/hr	0.00	30.34	0.00	30.34
CO	kg/hr	0.00	531.38	0.00	531.38
C-SOLID	kg/hr	0.00	0.00	0.00	0.00
ASH	kg/hr	0.00	92.73	92.73	0.00
CO2	kg/hr	0.00	330.34	0.00	330.34
Volume Flow	l/min	5.87	5536.86	0.44	5536.41

Units		S13	S14	S15	S16	S17
From		E-101	V-102	V-102	S-102	S-102
To		V-102		S-102		
Stream Class		MCINCPSD	MCINCPSD	MCINCPSD	MCINCPSD	MCINCPSD
Total Stream						
Temperature	C	20.00	20.00	20.00	20.00	20.00
Pressure	bar	25.33	25.33	25.33	25.33	25.33
Mass Vapor Fraction		0.84	0.00	1.00	1.00	1.00
Mass Liquid Fraction		0.16	1.00	0.00	0.00	0.00
Mass Solid Fraction		0.00	0.00	0.00	0.00	0.00
Mass Enthalpy	cal/gm	-1392.31	-3834.65	-925.08	-2.55	-1310.78
Mass Density	gm/cc	0.02	0.76	0.02	0.03	0.02
Enthalpy Flow	cal/sec	-621440.61	-274848.73	-346591.89	-281.24	-346324.16
Mass Flows	kg/hr	1606.81	258.03	1348.78	397.62	951.17
RICEHUSK	kg/hr	0.00	0.00	0.00	0.00	0.00
WATER	kg/hr	259.02	258.00	1.02	0.00	1.02
O2	kg/hr	0.00	0.00	0.00	0.00	0.00
N2	kg/hr	397.62	0.00	397.62	397.62	0.00
H2	kg/hr	58.12	0.00	58.12	0.00	58.12
CH4	kg/hr	30.34	0.00	30.34	0.00	30.34
CO	kg/hr	531.38	0.00	531.38	0.00	531.38
C-SOLID	kg/hr	0.00	0.00	0.00	0.00	0.00
ASH	kg/hr	0.00	0.00	0.00	0.00	0.00
CO2	kg/hr	330.34	0.03	330.31	0.00	330.31
Volume Flow	l/min	1155.08	5.67	1149.41	228.37	920.70

5   SIZING AND COSTING

5.1   Heat Exchanger (E-101)

Table 5: Sizing

Parameters	Symbol	Unit	Value	
liquid nitrogen	Inlet temperature	Ti	°F	-320
	Outlet temperature	To	°F	-320
Process fluid	Inlet temperature	ti	°F	900
	Outlet temperature	to	°F	20
	Logarithmic mean temperature difference	ΔTlm	°F	688.7588574
	Overall heat duty (from simulation)	Q	Btu/hr	3060458.55
	Overall convective heat transfer coefficient	U	Btu/ft2-hr	40
	Area available for heat transfer	A	ft2	111.0859961

Table 6: Costing

Parameter	Symbol	Unit	Value
Temperature	T	°F	1652
Pressure	P	psia	14.69
Material used is Stainsless steel			
Reference Cost (1969)	C0	$	5000
Area of heat transfer	S0	ft2	115.8
	α	dimensionless	0.65
Base cost (1969)	CB1	$	4866.738313
Update factor	UF	dimensionless	8
Base cost (2018)	CB2	$	38933.9065
Module factor	MF2	dimensionless	3.29
Material Factor	Fm	dimensionless	3.1
Pressure Factor	Fp	dimensionless	0
Design type factor	Fd	dimensionless	0.8
Correction factor	MPF	dimensionless	2.48
Total cost (2018)	C	$	185714.734

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