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A New Approach towards Production of Syngas as a Precursor for Manufacturing Ammonia

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Abstract: In this study, rice husk as biomass undergoes drying and gasification process to produce syngas. Moisture from biomass is removed to get dry biomass which is then gasified at 700℃. Ash is produced which is separated through separator and product gas is passed to heat exchanger to reduce its temperature. Finally, syngas is obtained which is a precursor for production of ammonia. The process simulation is done using Aspen Plus software. The model is validated and the effect of gasification temperature, gasification pressure, and equivalence ratio (ER) on gas component composition, gas yield, and gasification efficiency was investigated using Aspen Plus simulation.
Keywords: Rice husk, Biomass, Gasification, Aspen Plus, Syngas

I. INTRODUCTION

The world is on the verge of an energy crisis because of the excess use of natural resources. It is very critical to develop alternative and sustainable energy production methods. Biomass is a more powerful, scalable, and sustainable source of energy and other chemicals. Keeping scarcity with the dangers of fossil fuels in mind, scientists are increasingly interested in renewable energy sources. One of the most common types of renewable sources is biomass. The most notable characteristics of biomass are its clear carbon neutrality and its global availability. The rice husk is composed of silica, lignin, and other hard materials that aid in the protection of the grain during growth. The world's annual rice production is 759.6 million tons (503.9 million tons milled). Rice husks cover about 20% of the rice field area, resulting in 152 million tons of rice husk waste annually. Underground loose rice husk is an excellent candidate for energy production via combustion, gasification, or pyrolysis due to its high calorific value (16,720 kJ/kg). Rice husk can be efficiently combusted in a furnace to generate heat for subsequent use, such as parboiling in rice mills or drying rice paddies. Because of its low thermal conductivity, it can also be used as an insulator. It can also be used as an adsorbent toremove various contaminants from water and air.

Gasification is an alternative process that converts rice husk to synthesis gas in a reactor with a controlled amount of air. Syngas can be used to generate electricity or as a fuel for drying and cooking. Rice husk is used as a cooking fuel in rural communities via rice husk stoves. This model is intended to predict and analyze biomass gasification using RGibbs reactor and RYield reactor blocks. The model has been modified due to an insufficient balance of the RGibbs reactor to match the actual process that occurs in the rice husk gasifier to produce Syngas which is the precursor for the manufacturing of ammonia.

II. LITERATURE REVIEW

In [1], a 20 TPD rice husk bubbling fluidized bed gasifier was developed and researched. Gasification properties were also investigated at gasification temperatures ranging from 700 to 850 degrees Celsius, with ERs ranging from 0.20 to 0.35. (As the ER increased, H2, CO, and CH4 levels decreased while CO2 levels increased). The tar content of the product gas was measured and compared before and after passing through the gas scrubbing unit. The tar removal rate was 98%, which was very good for a gas engine. The formation of agglomerates caused a pressure drop in the lower part of the gasifier during the gasification operation. The fluidization properties of aggregates were investigated using CPFD simulations.

In [2], the production of syngas, an important biomass that is abundantly available all over the world is produced in dual fluidized gasifiers through the gasification process. Another advantage of this method is that it controls waste and pollutants. The results indicate that biomass is a larger enormous supply that updates fossil fuels and leads to inexperienced strength in a more reasonable way. This paper provides a high-level overview of previous works on the combustion and gasification of rice husk in atmospheric fluidized bed reactors and summarizes the state of the art. The reactor efficiency was estimated to have increased from 90-95%. In comparison to the fixed-bed reactor, the reactor conversion achieved was 92%. This demonstrates that the best combustion process can produce the least amount of ash. The catalytic gasification process in the TGA-MS system was successfully optimized using coal slag as a catalyst.

In [3], the basic design of a fluidized bed gasifier was carried out on pilot scale. According to the findings of the study, the proposed model can be a useful tool for predicting the performance variable values of pilot biomass fluidized bed gasifiers. (For each of the seven parts or subsystems, a design procedure was developed into which a gasifier was divided, with the goal of producing an energetic gas with around 70 kW of useful energetic power. Experiments with a gasifier built according to the designs revealed that the developed procedure was adequate, with a maximum deviation for the operational performancevariables close to 50%.)

In [4], using Aspen Plus, a biomass gasification model based on the Gibbs free energy minimization method was created. It intends to use the RGibbs and RYield reactor blocks to predict and analyze biomass gasification processes. The model was modified to fit the actual process occurring in the rice husk gasifier by imperfect equilibration of the RGibbs reactor. Based on Aspen Plus simulations, the model was validated and the effects of gasification temperature, gasification pressure, and equivalence ratio ER on gas component composition, gas yield, and gas efficiency were investigated. In [5], the laboratory-scale gasification of rice husks, sawdust, and coconut shells was carried out using a fixed-bed downdraft gasifier. The goal of this research is to compare the syngas generation properties and prospects of sawdust and coconut husks to rice husks. The maximum amount (vol%) of syngas-produced methane was achieved by using coconut husks instead of sawdust and rice husks, according to the experimental results. Furthermore, it has been demonstrated that gasifying coconut shells produce more hydrogen than sawdust or rice husks. Furthermore, emissions from coconut husk gasification are lower than those from rice husk gasification, which are even lower than emissions from fossil fuels. In Bangladesh, rice husks, sawdust, and coconut shells are inexpensive sources of biomass. Therefore, the results of this paper can be usedto provide clean and economical energy sources soon.

In [6], the one-dimensional steady-state pseudo-homogeneous model, which is widely used to study the behavior of industrial catalysts, was used to simulate the fixed catalyst bed. The Aspen Plus simulator was used for the second time to simulate a real WGS process at high pressure, and the reactor used was designed to obtain the true PFD and P&ID for this real process. In [7], the Aspen Plus single-compartment model was created to simulate the gasification of steam rice husks in fluidized bed gasifiers. Process parameters' effects on gasifier performance and effectiveness have been investigated. The maximum hydrogen yield at 1000 K was found to be 37.05% for an SBR of uniform and ER of 0.25. Kinetics in two reaction-combination compartment models may produce better results. In [8], according to the findings of this study, the higher the gasification temperature, the lower the calorific value, heat conversion efficiency, and carbon conversion. The gasifier's effective temperature for syngas production should be 800°C, with an air equivalence ratio of 0.2. Furthermore, the results show that the air equivalence ratio influences syngas production, with a higher air equivalence ratio increasing carbon conversion while decreasing calorific value. The lower calorific value is greatest at the smallest air-equivalent ratio and decreases as the ratio increases. A lower air equivalence ratio indicates a higher product gas concentration. High humidity may have no effect on carbonation. Furthermore, increasing the moisture content reduces the calorific value of the generated syngas. A higher moisture concentration, on the other hand, increases the efficiency of carbon conversionat a lower air-equivalent ratio.

In [9], using Aspen Plus, a simulation model for rice husk gasification in a fluidized bed gasifier was created. Except for methane, the results show good agreement between the simulated predictions and the experimental data. Stoichiometry can explain this, and tar formation hypotheses are dismissed. In the experimental study, the reaction rate and/or retention time may not be fast enough to reach the equilibrium condition.

III.METHODOLOGY

The Aspen PLUS (a market-leading process modelling environment for conceptual design, optimization, and performance monitoring for the chemical, polymer, specialty chemical, metals and minerals, and coal power industries) model is used in this work. We have used the Peng-Robinson equation of state property method for the simulation. Since Biomass and Ash are specified as non-conventional components, HCOALGEN property method is chosen for enthalpy and DCOALIGT is chosen for density for both Biomass and Ash components. Ultimate analysis is specified in Table 3, Proximate analysis is specified in Table 4. Organic is taken as 0.04 for the Sulphanal Attribute.

The simulation incorporated by the accompanying steps:

1) Stream class specification
2) Choice of property method
3) Specifying the component from the databank and distinguishing non-conventional and conventional components
4) Connecting unit operation blocks with material streams (defining the process flow sheet)
5) Feed stream specification (including specifying composition, thermodynamic condition and flow rate)
6) Specification of unit process blocks and chemical reactions where necessary.

Pre-assumptions made in displaying the gasification procedure are as per the following:

a) The process of simulation is keptunder a steady state condition.
b) No pressure drop and no heat loss are considered.
c) All considered components are in chemical equilibrium.
d) Sulphur, nitrogen, and chlorine in biomass are assumed to go to the gas phase.

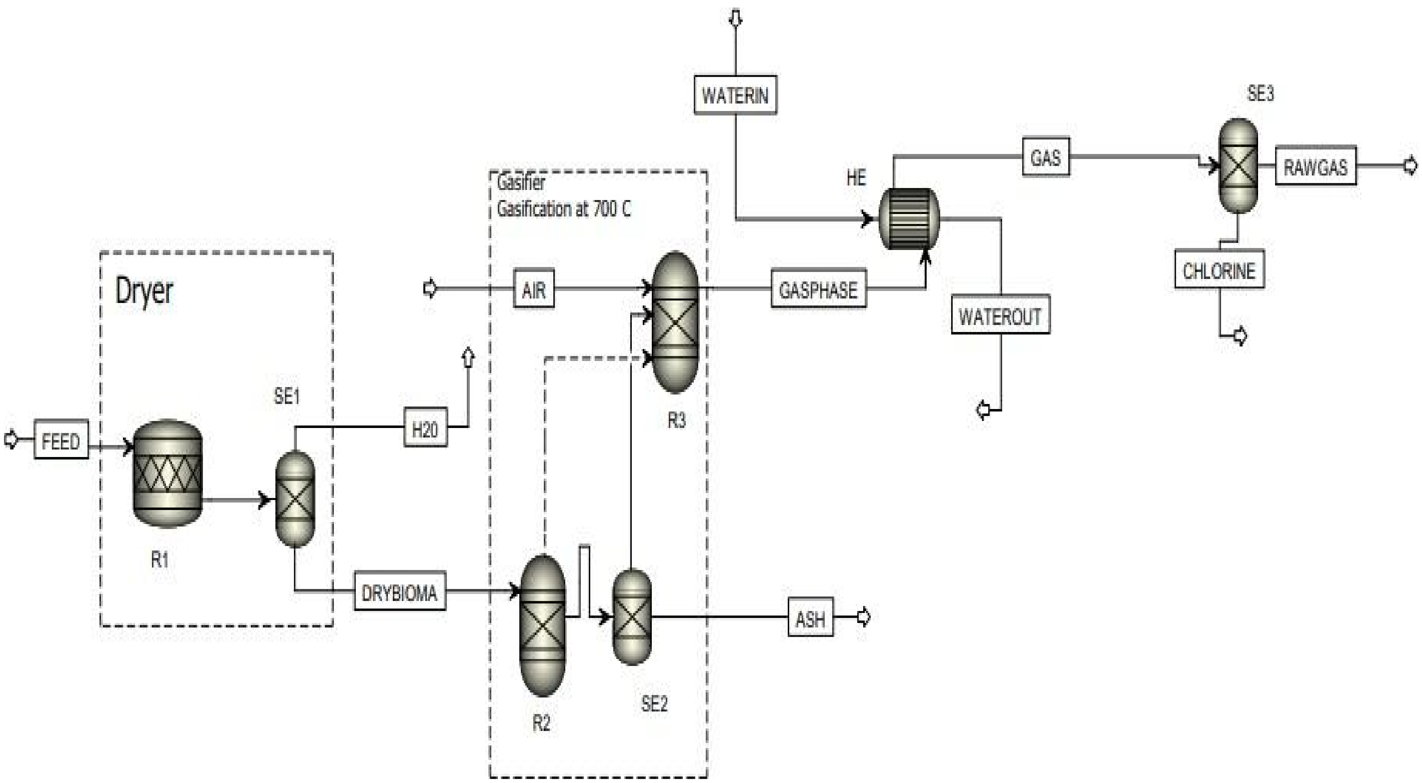

Fig. 1 Simulation Flowsheet

TABLE I
MODULE INFORMATION

Module symbol	Components	Module symbol	Components
R1	RStoic Reactor	HE	Two stream Heat Exchanger
R2	RYield Reactor	SE1, SE2, SE3	Component Separator
R3	RGibbs Reactor		

Fig.1 details the sequence of processes and separations used for manufacture of Syngas. Table 1 details the components as per the module symbol. Feed which is Biomass at 23 ℃ and 1 bar pressure having mass-flow of 2000 kg/hr, is passed through RStoic reactor operated at 100 degrees Celsius and 1 bar. Component attributes are added as the non-Conventional properties of the Biomass. Moisture and dry Biomass is separated in separator 1. Dry biomass is then ready for gasification. Dry biomass is passed to the RYield reactor operating at 700 ℃ and 1 bar pressure. Component yields are chosen as yield options. Table 2 consists of the basis yield for the components. Basis yield values are taken from the Ultanal component attributes results of the dry biomass.

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TABLE III
COMPONENT AND ITS BASIS YIELD

Component	Basis Yield
ASH	0.1826
C	0.3666
H_2	0.0437
N_2	0.0023
Cl_2	0.0876
S	0.0004
O_2	0.3168

Reaction produces Ash, separated using separator 2 from the feed stream. RYield, stream from separator 2 is passed to RGibbs reactor. Air stream is fed to the RGibbs reactor at 25 ℃ and 1 bar pressure with mole-fraction of 0.21 of oxygen and 0.79 of nitrogen, flow rate of 2400 kg/hr is fixed for the air flow. Calculate phase equilibrium and chemical equilibrium option is chosen as the calculation option for RGibbs reactor with pressure as 1 bar.

The product stream from R3 reactor is named gas phase which is at 700 ℃. The temperature of the stream is very high, so it is passed through heat exchanger HE to reduce its temperature to 200 ℃. 200 ℃ is chosen as the final stream temperature because at this temperature all the components of the stream will remain in the gas phase. Shortcut as model fidelity and countercurrent as shortcut flow direction is chosen for the heat exchanger. Cold stream outlet temperature specification at 200 ℃ and 1 ℃ as minimum temperature approach is chosen as the exchanger specification for the heat exchanger. Water is used as the coolant which is at 100 ℃ at 1 bar with 100 kg/hr as the mass flow. The cold gas consists of many impurities which must be separated to make it the proper composition of the Syngas. The gas is passed through the separator (SE3) to remove chlorine from the gas.

IV. RESULT AND DISCUSSION

Table 3 and Table 4 is the Ultimate Analysis and Proxanal Analysis of the rice husk respectively, the values are taken from the literature survey. Sulphanal Analysis is taken by estimation.

TABLE IIIII
ULTIMATE ANALYSIS

Types of Biomasses	Carbon (%)	Sulphur (%)	Hydrogen (%)	Nitrogen (%)	Oxygen (%)	Chlorine (%)
Rice husk	38.66	0.04	8.37	0.23	33.68	0.76

TABLE IV
PROXANAL ANALYSIS

Biomass Sample	Moisture Content (%)	Volatile Matter (%)	Ash Content (%)	Fixed Carbon (%)
Rice husk	11.2	48.34	18.26	22.2

Table 5 consists of the composition of the product stream named as raw gas which consists of many impurities which has to be removed in the further study. Sensitivity analysis were done on different parts of the process simulation. First was of the Air flow rate in the R3 reactor to maintain the temperature of 700℃ in the process and another was of the temperature in R2 reactor to maximize the CO composition in the product stream.

Figure 2 which the graph of air flow rate vs temperature of the product stream of the gasification process, the graph shows that on increasing the flow rate of the air, the temperature of the product stream also increases. Another sensitivity analysis as shown in Figure 3 was done on the temperature of the gasification process vs the CO content in the product stream (COPD), on studying the graph it is concluded that on increasing the temperature of the gasification process the CO content in the product stream decreases.

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TABLE V
RAW GAS COMPOSITION

Component	Flow (kg/hr)	Component	Flow (kg/hr)
H_2	60.16	NH_3	0.099
CH_4	10.8	H_2S	0.75
C_2H_4	7.46E-05	HCl	160
C_2H_6	6.49E-05	H_20	91.58
CO	1170.79	C	1.48
CO_2	511.01		
N_2	1845		

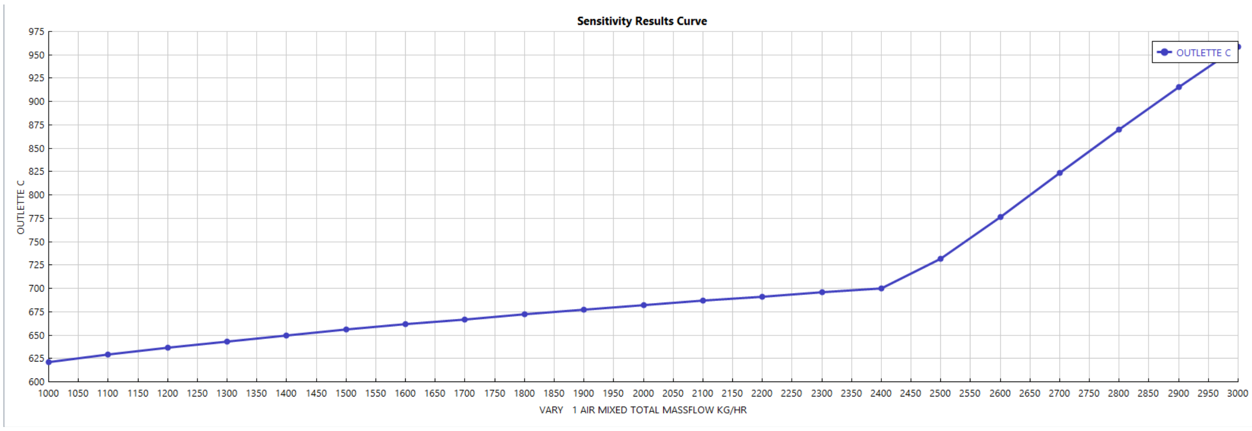

Fig. 2 Temperature vs Air Flow

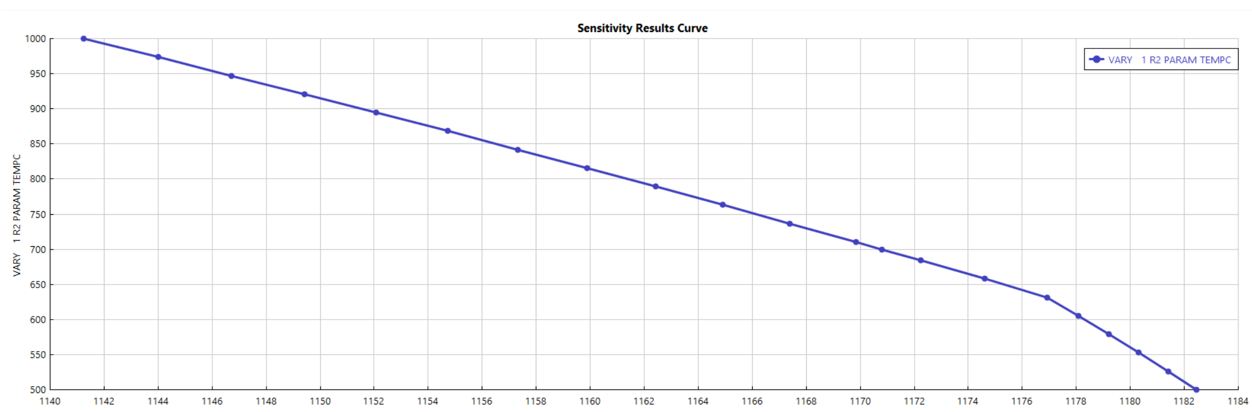

Fig. 3 Temperature vs COPD

V. CONCLUSION

Aspen plus model is used to design a process to produce Syngas from Rice husk by gasification process. The CO content stream flow in syngas is 1170.8 kg/hr, while the product stream flow is 3851.7 kg/hr. 700℃ is chosen for the gasification process as it is observed the CO composition in product stream decreases as the temperature of the gasification increases.

Composition of syngas consists of many impurities which will be removed in future to make it suitable for further process. Syngas will undergo water-gas shift reaction to produce H_2 which will react with N_2 to form ammonia. In this way, syngas becomes a precursor for production of ammonia.

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