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A Study on Gasification behavior of woody biomass Using ASPEN

Karan Nair[1], K.K. Jain[2]
[1] *Research Scholar, department of mechanical Engg. SRIT, Jabalpur (M.P)*
[2]*Professor, department of mechanical Engg. SRIT, Jabalpur (M.P)*

Abstract- **The use of wood for electricity generation and heat in modern (non-traditional) technologies has grown rapidly in recent years. For its supporters, it represents a relatively cheap and flexible way of supplying renewable energy, with benefits to the global climate and to forest industries. To its critics, it can release more greenhouse gas emissions into the atmosphere than the fossil fuels it replaces, and threatens the maintenance of natural forests and the biodiversity that depends on them.**

Biomass is classified as a source of renewable energy in national policy frameworks, benefiting from financial and regulatory support on the grounds that, like other renewables, it is a carbon-neutral energy source. The gasification can be the alternative way for woody biomass to cope up these threatens. A simulation based study has been carried out in this work for two woody biomass Kasai and Babool available in central India to find out the gasification behavior of both of them. The three gasification variables has been considered for the study i.e. Air to Biomass ratio, Gasification temperature and air inlet temperature.

Thus the objective of the study is

- **To present a simulation based investigation aimed at developing an efficient process for air gasification of woody biomass in the absence of added catalysts.**
- **To study the effect of the Air to Biomass ratio, Gasification temperature and air inlet temperature used for gasification process syngas quality.**

I. INTRODUCTION

1.1 General

Gasification innovation has been broadly used to deliver business energizes and chemicals. Current advancements in the compound assembling and oil refinery enterprises demonstrate that utilization of gasification offices to deliver combination gas will keep on rising. A striking element of the innovation is its capacity to deliver a dependable, top notch syngas item that can be utilized for vitality creation or as a building hinder for compound assembling forms.

What's more, it incorporates the capacity to house a wide assortment of vaporous, fluid, and strong feedstock. Traditional fills, for example, coal and oil, and also low-or negative-esteem materials and squanders, for example, oil coke, overwhelming refinery residuals, optional oil-bearing refinery materials, civil sewage muck, and chlorinated hydrocarbon results have all been utilized effectively in gasification activities. Biomass and harvest buildups additionally have honey bee gasified effectively. Gasification of these materials has numerous potential advantages over ordinary alternatives, for example, ignition or transfer by cremation.

1.2 Gasification Process

Amid gasification of biomass, the material is warmed to a high temperature, which causes a progression of physical and concoction changes that outcome in the advancement of unstable items and carbonaceous strong deposits. The measure of volatiles created and their organizations rely upon the reactor temperature, sort, and attributes of fuel material. It is for the most part acknowledged that the roast gasification organize is the rate constraining in the gasification of biomass in light of the fact that the devolatilization arrange is quick.

The composition of the final product gas is also dependent on the degree of equilibrium achieved by various gas-phase reactions, particularly the water-gas shift reaction. In the absence of a catalyst, gasification of char with reactive gases such as O_2, H_2O and CO_2 occurs at higher temperatures (700˚C to 1000˚C) according to the following reaction:

$$Char + Limited\ Oxygen\ \rightarrow Gas + Tar + Ash$$

When char is gasified in the presence of steam, the gas produced is composed mainly of CO_2, CO, H_2

and CH_4. Steam may be added from an external source or from the dehydration reactions of crop residues. In reactors operating at low temperatures, low heating rates and very high pressure, secondary reactions are very
important because of long residence times (of the volatile products in the reaction zone). On the other hand, at low pressure, high temperature, and high heating rates, most of the volatile products escape instantaneously from the fuel particles during pyrolysis, hence reducing the chances of a solid char-gas interaction. In fluidized bed gasifier, the latter prevails but because of the mixing nature of the bed, secondary reactions in the gas-solid and gas-gas phases take place.
Thermal decomposition of woody products starts at temperatures as low as 160˚C when water distillate, known as "pyroligneous acid," is developed. However, because the major product of biomass below 600˚C is char, crop residue gasification processes are usually designed to operate at temperatures above this point. Finally, higher temperatures are needed to attain considerable rates and levels of char conversion to a gaseous creation, which is the basically aim of biomass gasification. The biomass gasification process happen in four consistent stages:

1) Dehydrating of the feedstock;
2) Pyrolysis to yield volatile matter with char;
3) Gasification of in situ formed char with reactive gases like as CO_2, H_2O, H_2 and O_2; finally
4) Secondary reactions of primary gases with tars.

2 LITERATURE REVIEW

Many researchers have been work for the gasification of Woody biomass, some of them are as:
"Influence of controlled handling of solid inorganic materials and design changes on the product gas quality in dual fluid bed gasification of woody biomass", 2018, Matthias Kuba, Stephan Kraft, Friedrich Kirnbauer, Frank Maierhans, Hermann Hofbauer Utilizing biomass feedstock in thermal conversion technologies to reduce greenhouse gas emissions is a promising way to substitute for fossil fuels. Gasification of biomass allows for the production of electricity, district heat, high-grade fuels for transportation and synthetic chemicals. Investigations at the HGA Senden industrial scale dual fluidized bed gasification power plant have shown the potential for improving gas quality by the controlled handling of solid inorganic materials in the reactor. Two measures for optimization were implemented and investigated on-site. First, improving the bed material and ash loops in the system led to significant reduction of undesirable tars in the product gas. This was based on reutilizing used, layered, olivine particles with higher catalytic activity compared to that of fresh olivine. Second, improving the mixing of feedstock or char particles with catalytically active bed material in the gasification reactor, and also ensuring steam, as reaction medium, was available local to the area of the fuel input, led to further decrease of tars in the product gas. This was achieved by incorporating additional fluidization nozzles in the gasification reactor.
In summary, the optimization measures for controlled handling of inorganic materials had a major influence on the product gas quality in the dual fluidized bed gasification of biomass. As a consequence, long-term operation at significantly higher capacity than before could be achieved at the HGA Senden industrial-scale power plant.
"Life Cycle Assessment of a Sewage Sludge and Woody Biomass Co-gasification System". 2017, Srikkanth Ramachandran, Zhiyi Yao, Siming You, Tobias Massier, Ulrich Stimming, Chi-Hwa Wang
Supplanting a piece of vitality got from non-renewable energy sources with bioenergy got from strong waste streams might be a promising technique to handle the double emergency of expanding waste heap up and worldwide environmental change. In this examination we propose a decentralized sewage slop and woody biomass co-gasification framework for Singapore. We assess the ozone harming substance discharge of the proposed framework and contrast it with the current framework through life cycle evaluation.
"Gasification behavior of coal and woody biomass: Validation and parametrical study", 2016, Idowu Adeyemi , Isam Janajreh, Thomas Arink, Chaouki Ghenai, The entrained stream gasification of two feedstocks (Kentucky coal and woody biomass) have been examined in this examination both numerically and tentatively. Beforehand, there had been no examination that researched the centerline parameters amid the trial gasification of Kentucky coal and

biomass using drop tube reactor (DTR). These great centerline tests gives enough information to high devotion demonstrate advancement and utilized for an inventive gasifier outline. This work explores the gasification conduct of Kentucky coal and wood squander under various gasification parameters including proportionality proportion, weight and temperature. The trial consider was led noticeable all around blown air DTR test office at the Waste-2-Energy Laboratory at Masdar Institute. The deliberate centerline temperature, leave gas organization, and SEM pictures was acquired for show approval and to increase better understanding into the gasification of the two distinctive feedstock particles. The Lagrangian– Eulerian based numerical model anticipated the test comes about sensibly. The impact of the fuel write on the gas structure along the centerline of the gasifier showed that Kentucky coal achieved higher gasification productivity when contrasted with that of wood squander. Besides, the gasification proficiency was most delicate to the equality proportion.

"Simulation of air-steam gasification of woody biomass in a bubbling fluidized bed using Aspen Plus: A comprehensive model including pyrolysis, hydrodynamics and tar production", 2016, Jennifer H. Pauls, Nader Mahinpey, Ehsan Mostafavi

A far reaching model was created to reproduce gasification of pine sawdust within the sight of both air and steam. The proposed display enhanced the start of a current ASPEN PLUS-based biomass gasification demonstrate. These upgrades incorporate the expansion of a temperature-subordinate pyrolysis demonstrate, a refreshed hydrodynamic model, more broad gasification energy and the consideration of tar arrangement and response energy. ASPEN PLUS was comparably used to reproduce this procedure; nonetheless, a more-broad FORTRAN subroutine was connected to fittingly demonstrate the complexities of a Bubbling Fluidized Bed ("BFB") gasifier. To affirm legitimacy, the precision of the model's expectations was contrasted and genuine trial comes about. Likewise, the relative precision of the far reaching model was contrasted with the first base-model to check whether any change had been made. Results demonstrate that the model predicts H2, CO, CO2, and CH4 sythesis with sensible precision in fluctuating temperature, steam-to-biomass, and identicalness proportion conditions. Mean mistake amongst anticipated and test comes about is ascertained to go from 6.1% to 37.6%. Most elevated relative exactness was gotten in CO piece forecast while the outcomes with the slightest precision were for CH_4 and CO_2 estimation at evolving steam-to-biomass proportions and equality proportions. At the point when contrasted with the first model, the complete model forecasts of H_2 and CO molar portions are more exact than those of CO_2 and CH_4. For CO_2 and CH_4, the first model anticipated with tantamount or better exactness while differing steam-to-biomass proportion and identicalness proportions yet the far reaching model performed better at different temperatures.

3 RESEARCH METHODOLOGY

3.1 Woody Biomass used for Gasification Process

Supply of biomass is essentially from fills that are home developed or gathered by family units for possess needs. The Government supported social ranger service program has added to fuel-wood supply to the tune of 40 million tons every year (Ravindranath and Hall, 1995).

The real classifications of biomass for vitality are woody rural buildups, agro-modern and logging deposits and wood from backwoods, devoted vitality ranches and town trees. Woody biomass for vitality could be gotten from, to begin with, clearing of or extraction from regular woodlands; second, reasonable extraction from timberlands and from the deposits of the timber preparing industry; and third, from committed vitality manors.

For this study the wastes from two different sectors i.e. Saw mill residues and residues from plywood industry has been considered for gasification process which are directly combusted in various kilns as the source of energy.

(a) Kasai Saw Dust

(b)Babool Saw Dust

Figure 3.1 Saw Dust for both the Biomass (Kasai and Babool)

3.2 Characterization of Woody Biomass

Kasai (Pometia pinnata, Pometia tomentosa) and Babool (Acacia nilotica subsp. Indica) saw dust are considered for the study. The ultimate and proximate analysis is carried out.

The results obtained are depicted in table 4.1.

Table 4.1 Ultimate and Proximate Analysis

Proximate Analysis		
	Babool	Kasai
Moisture content (%wb)	10.2	14.5
Volatile mater (%db)	66.47	63.1
Ash content (%db)	2.8	6.6
Fixed carbon (%db)	20.53	15.8
Ultimate Analysis		
C	47.42	36.49
H	5.792	7.5
N	0.87	0.95
O	42.92	48.46
Ash	3	6.6

3.3 Simulation of Gasification using Aspen Plus

The gasification process is carried out using R Gibbs reactor (GASIF). WBIOMASS represents the feed stream for gasification process. Air is supplied at 25˚C temp and 1 bar pressure represents by AIRGAS stream. The product of gasification process is supplied to another block SEP which seperates the gaseous product to the ash. This gaseous product is thus supplied to the third block functioned as a boiler (R Stoic reactor used), It is placed for combustion of the produced syngas. For combustion air is supplied to the COMBUST block using AIR stream. Figure 3.2 represents the Flow sheet used for the process.

The following assumptions has been considered for the study.

- The working process is steady state and the model is steady state kinetic model;
- The process occur in isothermal system;
- Tars are supposed as non- equilibrium yields to decrease the hydrodynamic difficulty
- Sulphur converts in H2S and N2 converts in only NH3 forms, no nitrogen oxides are produced;

The Peng-Robinson equation of state with Boston-Mathias modifications was nominated as the property method used for the model. The Peng-Robinson equation are widely used in industry. The advantages of these equation is that it is easy to use and that they often accurately represent the relation between temperature, pressure, and phase compositions in binary and multicomponent systems.

This condition just require the basic properties and acentric factor for the exhaustive imperatives. Slight PC properties are required and those prompt not too bad stage harmony connection. However, the accomplishment of these changes is restricted to the estimation of stage balance weight. The proposed immersed fluid volumes are not upgraded and they are constantly higher than the deliberate information.

The biomass lower heating value (LHV) was also specified with the HCOALGEN and DCOALIGT property models chosen to estimate the biomass enthalpy of formation, specific heat capacity and density based on the ultimate and proximate analyses.

The main gasification reactions are as

Heterogeneous Equation

$C + 2H_2 \leftrightarrow CH_4$ ……….. (3.1)

$C + H_2O \leftrightarrow CO + H_2$ ……….. (3.2)

$C + CO_2 \leftrightarrow 2CO$ ……….. (3.3)

Homogeneous Equation

$CH_4 + H_2O \leftrightarrow CO + 3H_2$……….. (3.4)

$CO + H_2O \leftrightarrow CO_2 + H_2$……….. (3.5)

NH_3, H_2S and HCl formation reactions

$0.5N_2 + 1.5H_2 \leftrightarrow NH_3$ ….…….. (3.6)

$H_2 + S \leftrightarrow H_2S$ ….…….. (3.7)

$Cl_2 + H_2 \leftrightarrow 2HCl$ ….…….. (3.8)

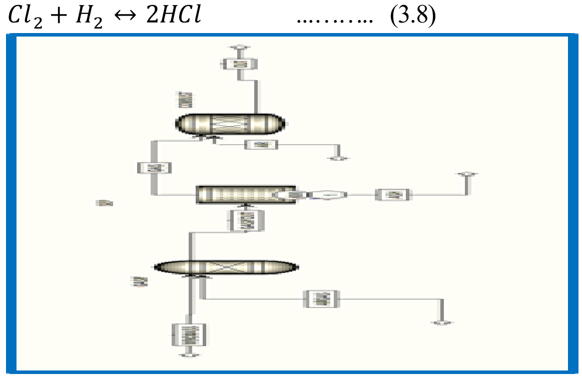

Figure 3.2 Flow Sheet of Gasification Process using Aspen Plus

4 RESULT ANALYSIS

To find out the effect on syngas composition the three parameters are considered for the analysis i.e. Gasification temperature, Air Temperature and Equivalence ratio.

4.1 Gasification Temperature:

The impact of gasification temperature on Lower heating value is shown in figure 4.1 and 4.2 for Kasai and Babool respectively.

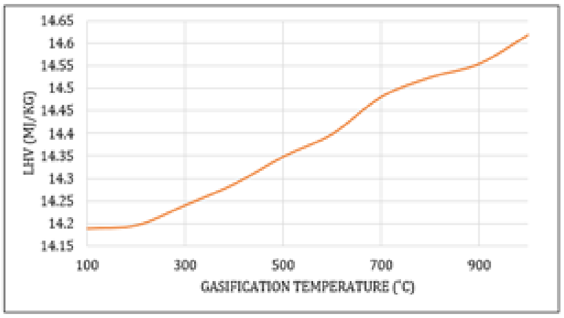

Figure 4.1 LHV corresponding to Gasification Temperature (for Kasai)

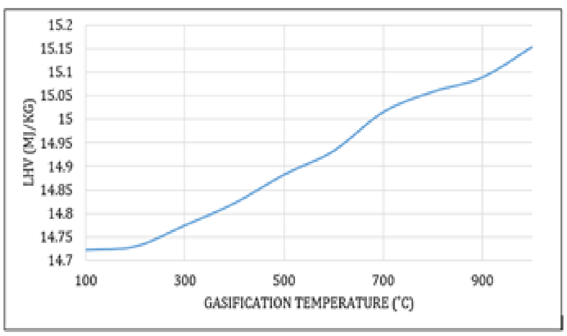

Figure 4.2 LHV corresponding to Gasification Temperature (for Babool)

In both cases the Lower heating value increases with the increment of Gasification temperature. The gasification process was conducted under different temperature conditions varying from 100˚C to 900°C by increasing the temperature at a step size of 100°C.

Figure 4.3 and 4.4 shows the Syn Gas component percentage with respect to the Gasification Temperature for both the biomass Kasai and Babool respectively. The application of higher heating rates increased from 100°C to 900°C, allows the formation of a reasonable amount of CO, but such temperature increases resulted into a decrease in H2 molar concentration.

In this study, CO2 molar concentration reduction was observed in both the cases. The LHV indicates that the temperature level must be chosen as high as possible. However, upper limits are set due to the ash content and ash melting behavior of the biomass.

The drawback of increasing the gasification temperature is increasing the CO percentage.

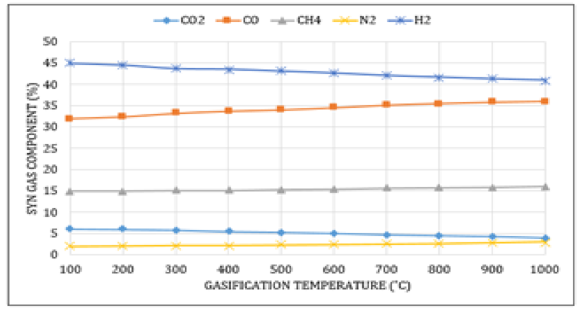

Figure 4.3 SYN Gas Composition corresponding to Gasification Temperature (for Kasai)

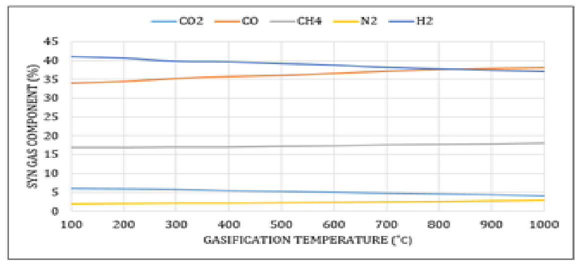

Figure 4.4 Syn Gas Composition corresponding to Gasification Temperature (for Babool)

4.2 Inlet Air Temperature:

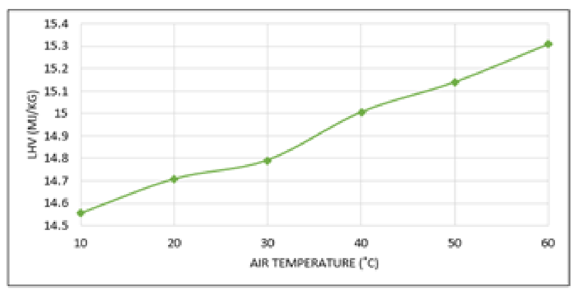

Figure 4.5 LHV corresponding to Air Temperature (for Kasai)

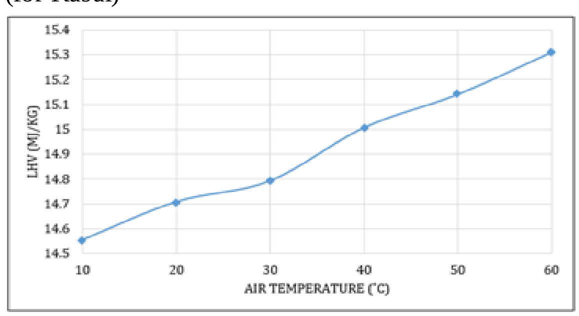

Figure 4.6 LHV corresponding to Air Temperature (for Babool)

The impact of Inlet Air temperature on Lower heating value is shown in figure 4.5 and 4.6 for Kasai and Babool respectively. The same tradition has been shown as same as Gasification temperature.

Figure 4.7 and 4.8 shows the variation in Syn gas components with respect to Air inlet temperature. CO2 and H2 shows the decrement in composition while CO, N2 and CH4 shows the increment trends in figure.

Reduction in CO2 and increment in CH4 is helpful for the quality improvement of Syn gas thus increases the LHV of the fuel gas. In a gasification system, there is no one constant temperature at which the system is operated as every step, throughout gasification, may hold a different temperature.

It is suggested that a pre-heater should be installed prior to the gasifier to raise the temperature of the oxidant by which conversion efficiency, heating value of syn gas produced and its quality can be increased whilst reducing tars and char residues.

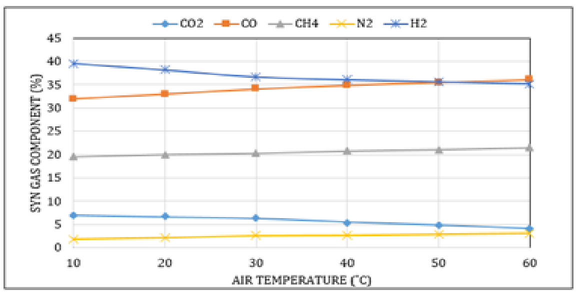

Figure 4.7 Syn Gas Composition corresponding to Air Temperature (for Kasai)

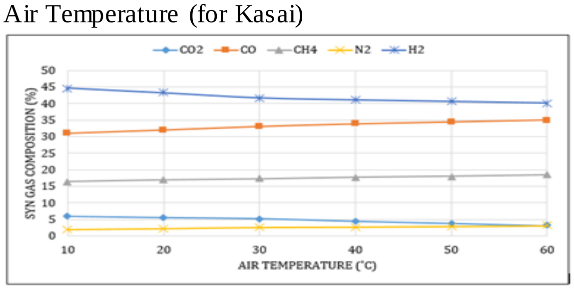

Figure 4.8 Syn Gas Composition corresponding to Air Temperature (for Babool)

4.3 Air to Biomass Ratio

The impact of Air to Biomass ratio on Lower heating value is shown in figure 4.9 and 4.10 for Kasai and Babool respectively.

Feeding of a biomass to a gasifier may affect energy efficiency obtained from a given gasification process. Overall process conversion efficiency may be reduced if the biomass has been overfed to the gasifier by which plugging caused thus optimum Air to Biomass ratio required. Less or Excess amount of Biomass with air are caused higher oxidation and plugging respectively.

Having air to biomass ratio about 0.5 to 0.6 shows the optimum condition and depicts the higher value of heating rate.

About 15.2 and 14.8 MJ/Kg of Lower Heating Value can be achieved having the optimum 0.5-0.6 Air to Biomass ratio for Kasai and Babool respectively.

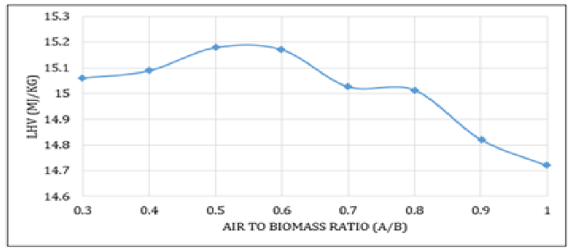

Figure 4.9 LHV corresponding to Air to Biomass Ratio (for Kasai)

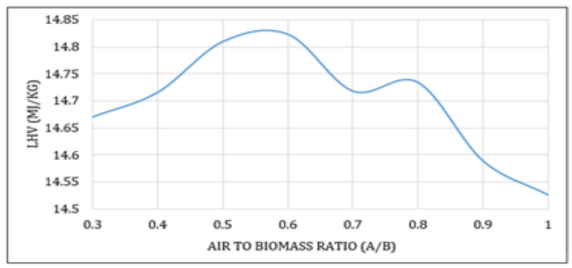

Figure 4.10 LHV corresponding to Air to Biomass Ratio (for Babool)

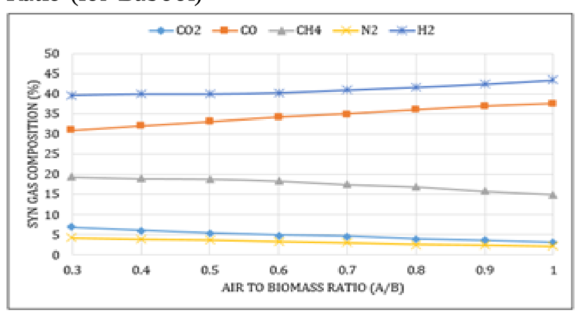

Figure 4.11 Syn Gas Composition corresponding to Air to Biomass Ratio (for Kasai)

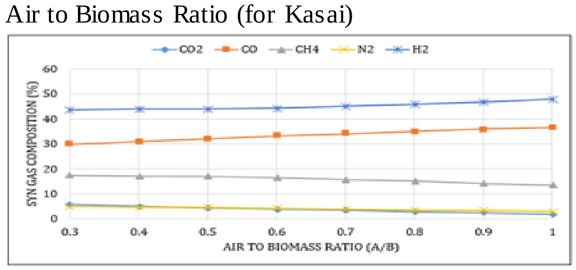

Figure 4.12 Syn Gas Composition corresponding to Air to Biomass Ratio (for Babool)

5 CONCLUSION

For prediction of the syn gas quality resulted from the gasification process of two basic woody biomass Kasai and Babool has been done with the help of Aspen Plus simulation environment. A model-based approach can be helpful for the prediction of the syngas quality as a function of the gasification temperature for a real case study.

In this work the Syn gas composition was predicted with respect to the various variables i.e. Air to Biomass ratio, Gasification temperature and air inlet temperature provided to the thermal processes, i.e. by varying the amount of air supplied, varying the temp of gasification and inlet air.

The following observations can be concluded

- Lower heating value increases with the increment of Gasification temperature. The application of higher heating rates increased from 100°C to 900°C, allows the formation of a reasonable amount of CO, but such temperature increases resulted into a decrease in H_2 molar concentration. In this study, CO_2 molar concentration reduction was observed in both the cases while increasing the gasification temperature. The LHV indicates that the temperature level must be chosen as high as possible. However, upper limits are set due to the ash content and ash melting behavior of the biomass.
- The same tradition has been shown in increasing the air inlet temperature, as same as Gasification temperature. CO_2 and H_2 shows the decrement in composition while CO, N_2 and CH_4 shows the increment while increasing the air inlet temperature. Reduction in CO_2 and increment in CH_4 is helpful for the quality improvement of Syn gas thus increases the LHV of the fuel gas. In a gasification system, there is no one constant temperature at which the system is operated as every step, throughout gasification, may hold a different temperature. It is suggested that a pre-heater should be installed prior to the gasifier to raise the temperature of the oxidant by which conversion efficiency, heating value of syn gas produced and its quality can be increased whilst reducing tars and char residues.
- Having air to biomass ratio about 0.5 to 0.6 shows the optimum condition and depicts the higher value of heating rate. About 15.2 and 14.8 MJ/Kg of Lower Heating Value can be achieved having the optimum 0.5-0.6 Air to Biomass ratio for Kasai and Babool respectively

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