Experimental Study of Fluidized Bed Gasifier using Coir Pitch, Rise Husk, Saw Dust – A Review

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Abstract— A great interest in environment friendly alternative energy sources that can reduce dependency on fossil fuels has been rising. The conversion of biomass to chemical energy commonly takes via thermo-chemical and bio-chemical tools. Among thermo-chemical conversion, gasification converts biomass into burnable gases, such as H2, CO, CH4 that can be used in boilers and in internal combustion engine or turbine to produce electricity generation. Fluidized beds are used for a wide variety of fuels; this flexibility with respect to different fuels is actually another stronghold of fluidized beds. The fluidization principle is straight forward: passing a fluid upward through a filled bed of solids produces a pressure drop due to fluid drag. Several researchers had worked on bubbling fluidized bed gasifier and use sized biomass like sawdust, rise husk, coir pitch, and olive pits, and coconut shell. But with biomass used as fuel in fluidized bed Gasifier with good quality of producer gas can be achieve by changing equivalence ratio and fluidization velocity.

Key words: Fluidized Bed, Bio Mass, Methane (CH4), Equivalence, Fluidization Velocity

I. Introduction

A. *History of Gasification*

The procedure of generating energy using the gasification method has been in use for more than 180years.during that time coal and peat were used to power these plants. Initially developed to produce town gas for lighting & cooking in 1800s. This was replaced by electricity and natural gas. It was also used in blast furnaces during both world wars especially Second World War the need of gasification produced fuel remerged due to the shortage of petroleum. Wood gas producers, called Gasogene or Gazogene.

B. *Gasification Process*

Gasification is a process that converts carbonaceous material such as coal, petroleum into carbon monoxide (CO) and Hydrogen (H2) by reacting with raw material at high temperatures with controlled amount of Oxygen (O2) and steam (H2O). The resultant gas mixture (CO + H2) is called synthesis gas or syngas. Gasification is method forremoving energy from almost any type of organic material such as wood, biomass.

C. *Biomass Pyrolysis*

Biomass pyrolysis is define as the thermal decomposition of biomass in the absence of an oxidizing agent (air/oxygen) and occurs at temperatures in range of 400 ºC to 800 ºC. With the addition of heat the biomass breaks down to condensable vapour, non-condensable gases (pyrolysis gas), and charcoal. The pyrolysis gas contains carbon monoxide, carbon dioxide, hydrogen, methane and higher hydro carbons.

II. Types of Gasifier

– Moving Bed Gasifier
– Fluidized Bed Gasifier
– Entrained Flow Gasifier

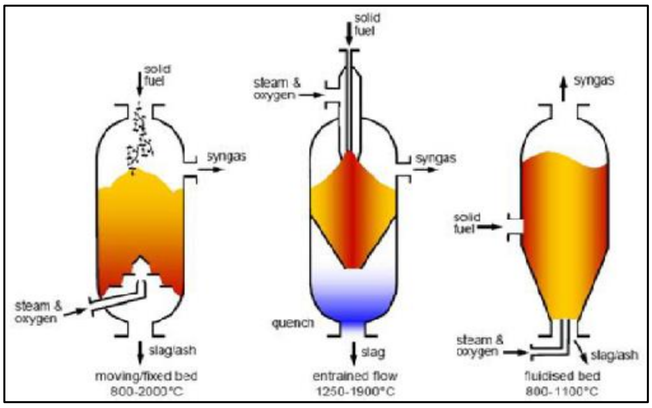

Fig. 1: Types of Gasifier [6]

A. *Moving Bed Gasifier*

In a moving bed gasifier, air flow s through a fixed bed of solid fuel particles as shown fig. 1. Fresh coal is served from the top, while air or oxygen is inserted from the bottom. This arrangement, the steam and oxygen /air feed is counter-current to the coal feed, is referred to as "updraft" or counter-current moving bed Gasifier. The syngas exits from the upper part of the gasifier.

Moving bed gasifier has the following characteristics:

– Small oxidant constraint;
– Moderately high methane content in the produced gas;
– Production of hydrocarbon liquids such as tars an oils;

B. *Fluidized Bed Gasifier*

A figure of fluidized bed gasifier is shown in fig. 1. A fluidized bed gasifier is a back-mixed or well-stirred reactor in which there is a constant mixture of new coal particles mixed in with older, partially gasified and fully gasified particles. The mixing also fosters uniform temperature throughout the bed. It is also significant that the temperature within the bed is less than the initial ash fusion temperature of the coal to avoid particle accumulation.

Generic features of fluidized bed gasifier:

– Wide-ranging solid recycling;
– Even and moderate temperature;
– Moderate oxygen & steam requirement;

C. *Entrained Flow Gasifier*

A figure of entrained flow gasifier is shown in fig. 1. Finely ground coal is introduce in co-current flow with the oxidant. Coal rapidly heated and reacts with the oxidant. The residence time of an entrained flow gasifier is on the order of seconds or tens of seconds. Due to short residence time, gasifier must operate at high temperature to achieve high carbon conversion.

Generic characteristics of entrained flow gasifier:

– High temperature slugging operation;
– Entrained of some melted slag in the raw syngas;
– Excess of sensible heat in the raw syngas;

III. Basic Terminology

A. Equivalence Ratio (ER)

The ratio of the fuel-to-oxidizer ratio to the stoichiometric fuel-to-oxidizer ratio. [9]

$$\text{ER: } \frac{\text{fuel to oxidizer ratio}}{\text{stoichiometric ratio}}$$

B. Minimum Fluidization Velocity

The superficial velocity at which upward drag force exerted by the fluid is equal to the apparent weight of the particles in the bed.

Velocity at which the pressure drop reaches to maximum, at that point the velocity is called as minimum fluidization velocity.

For minimum fluidization velocity we increase the flow of fluid in the bed to be fluidized. [9]

C. Efficiency of Gasifier

Gasifier efficiency is the ratio of total energy in supply fuel and total energy in producer gas. [9]

IV. Literature Review

Several researchers had worked on bubbling fluidized bed gasifier. Experimental investigation has been carried out in a pilot scale fluidized bed rice husk gasifier. The study investigated the effect of temperature and the equivalence ratio on fuel gas composition. Gasifier temperatures were in the range of 600ºC - 800ºC with equivalence ratio 0.25, 0.35, and 0.45. The experimental tests were carried out to determine the influence ratio and bed temperature on fuel gas compositions and gas yields.

A. Factor Influencing Gasification Process

1) Bed Temperature

The gasification rate as well as the overall performance of the Gasifier is temperature- dependent. All gasification reactions are normally reversible and the equilibrium point of any of the reactions can be shifted by changing the temperature. As part of a wider investigation, Harris et al. (2005) presented gasification conversion data for a suite of Australian coals reacting with oxygen/nitrogen mixtures at 2.0 MPa pressure and at temperatures up to 1773 K. Combustible gas concentration increased with increases in temperature. Char yield decreased with increases in temperature. Scott et al. (1988) reported that the product gas yield from maple sawdust (1.4 %) increased as the reactor temperature increased whereas the liquid and solid products decreased with increases in temperature. The decreasing amount of char indicated that the conversion increased with increases in temperature.

2) BED height

At a given reactor temperature, a longer residence time (due to higher bed height) increases total gas yields. Sadaka et al. (1998) showed that a higher bed height resulted in greater conversion efficiency as well as a lower bed temperature due to the fly-wheel effect of the bed material. The fly-wheel effect is significantly reduced when the amount of bed material is reduced thereby resulting in higher bed temperature. Their results also reported that increasing the bed height increases the bed pressure drop in the dense bed but resulted in no significant changes in the freeboard region. Beaumont and Schwob (1984) found that at a temperature of 350ºC, water yield increased with increases in vapor residence time during the pyrolysis Process of wood in an N2 atmosphere. [11]

3) Fluidization velocity

Fluidization Velocity plays an important role in the mixing of particles in the fluidized bed. In air gasification systems, the higher the fluidization Velocity the higher the bed temperature and the lower the produced gas heating value due to increased amounts of oxygen and nitrogen in the inlet gas to the system. Sadaka et al. (2002) reported that the higher heating value reached its peak value at a fluidization Velocity of 0.28 m/s but remained fairly constant at the fluidization Velocity of 0.33 and 0.37 m/s. However, Raman et al. (1980) tested the gasification of feedlot manure with different superficial gas Velocity. They found that the tested range of superficial Velocity did not have a significant influence on produced gas yield, composition, or heating value due to the tested small range. [11]

4) Equivalence Ratio

The equivalence ratio has the strongest influence on the performance of Gasifiers because it affects bed temperature, gas quality, and thermal efficiency. Increasing the equivalence ratio resulted in lower pressure drops both in the dense bed and the freeboard regions when the Gasifiers operated at different fluidization Velocity and bed heights. Schoeters et al. (1989) reported that high equivalence ratios increased the gas production rate in air gasification. The Gasifier temperature was found to increase with increases in the equivalence ratio because of increases in the exothermic reactions. On the other hand, a very low equivalence ratio results in very low bed temperatures, thus producing a lower gas and higher tar yields. Ergudenler and Ghaly (1992) reported that the combustible components and the heating value of the produced gas decreased with decreases in the equivalence ratio. At the equivalence ratios of 0.25, 0.20 and 0.17, the higher heating value of the produced gas were 6.48, 6.19 and 5.98 MJ/Nm³, respectively. [11]

5) Air/Steam Ratio

Increasing the air to steam ratio increases the gas heating value until it peaks. Tomeczek et al. (1987) used an air-steam mixture in the gasification Process of coal in a fluidized bed reactor. The results showed that the influence of steam-to-air ratio on char was particularly strong at lower ratios due to the fact that the steam released at the devolatilization stage contributed to the gasification Process even in the case when steam was not added. When the steam-air ratio increased, the heating value increased, reaching its peak at 0.25 kg/kg. Schoeters et al. (1989) investigated the effect of the air-to-steam ratio on the gasification of wood shavings. An increase in the steam flow rate resulted in an increase in the heating value and the energy recovery because the reactor was heated from outside, which helped to keep the temperature constant without any adjustment of the flows. Halligan et al. (1975) gasified feedlot manure using a mixture of air and steam in a bed consisting exclusively of the feed material. Over a temperature range of 966 to 1069 K, increasing the steam-to-air ratio increased the gas volumetric yield and the heating value from 0.6 to1.3 m³/kg. And from 8.7 to 9.8 MJ/m³, respectively. Energy recovery and carbon conversion also increased with temperature from 23 to 49% and 20 to 50%, respectively. [11]

V. STUDY OF GASIFICATION PROCESS FOR DIFFERENT FUEL

P. Subramanian (2010) studied the factors affecting fluidized bed gasification of coir pith, rice husk and saw dust and Process optimization, experiments were conducted in a 40 kg/h Fluidized bed Gasifier at equivalence ratios of 0.3, 0.4 and 0.5. The hot gas efficiency of the system was in the range of 41.59–82.80%. It is observed that with the increase of Equivalence ratio, CO2 content was increasing whereas CO was reducing. The fluidized bed Gasifier system is useful for thermal applications and power generation in agro industries viz. coir industry, rice mills, timbering and other small- scale industry. They reported that reduction in carbon monoxide content with increase of equivalence ratio, whereas CO was increased with increase of gasification Process time. The value of carbon monoxide was in the range of 8.24–12.68%, 9.32–19.55% and 12.39–17.73% for coir pith, rice husk and sawdust, respectively and carbon dioxide content indicated that, with the increase of equivalence ratio from 0.3 to 0.5, the CO2 content was also increasing. The maximum (16.24%) and minimum (11.05%) value of CO2 was observed at 0.5 and 0.3 ERRespectively, in coir pith gasification. The minimum (10.21% and 10.78%) and maximum (17.14% and 16.84%) content of CO2. Was observed with 0.3 and 0.5 ER for rice husk and sawdust gasification, respectively.

A. *Steam Gasification*

Unlike air gasification, steam gasification requires an external heat source if steam is used as a sole gasifying agent. Using a mixture of steam and air as a gasifying agent is not uncommon technology and has, in fact, been studied by several researchers. Oxygen in the air will help to provide the required energy due to the exothermic nature of burning biomass. The elevated temperature will help in the devolatilization Process of biomass to produce various gases. Steam will react with carbon monoxide to produce hydrogen and carbon dioxide. The principle gas-phase reaction in the steam gasification system is the water gas-shift reaction:

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

Compared to air gasification, steam gasification produces a higher energy content producer gas. Boateng et al. (1992) determined the effects of reactor temperature and steam to biomass ratio on producer gas composition, heating value and energy recovery. The produced gas, which is rich in hydrogen, had been found to have a heating value ranging from 11.1 MJ/m³ at temperature of 700ºC to 12.1 MJ/m³ at temperature of 800ºC. Energy recovery varied from 35-59% within the same temperature range. Hoveland et al.(1982) studied corn grain-dust gasification in a0.05 m I.D. fluidized bed Gasifier using steam as a fluidizing agent and a mixture of sand and limestone as the bed material. The produced gas yield increased from 0.13 m³/kg at 867 K to 0.73 m³/kg at 1033K. The gas heating value increased from 9.4 to 11.5 MJ/m³ at the same temperature range.The gas yield increased from 0.38 to 0.55 m³/kg and the heating value varied from 16.8 to 18.5 MJ/m³. Over this temperature range, H2, CH4, CO, and CO2 concentrations in the produced gas varied from 3.6-13.1%, from 14.4-13.5%, from 52.2- 51.1% and from 23-14.6%, respectively. The balance of the product gas was comprised of higher hydrocarbons including ethane, ethylene, and propylene. Corella et al. (1989) reported on steam gasification of four different crop residues (wood chips, thistle, saw- dust and straw) in a 0.15 m I.D. fluidized bed Gasifier. They determined the gas, char, and tar yield at temperatures between 650-780ºC for each type of crop residue. Straw and sawdust exhibited higher gas and lower tar yields compared to wood chips. [14]

Sr. No.	ER	Time Minute	CO %	CO_2 %	H_2%	CH_4%	N_2%	O_2%	Gas YieldNm³/Kg	H.H.VNm³
1	0.30	10	08.71	14.62	08.49	1.52	66.41	0.25	1.98	2.65
2		20	09.26	14.88	07.89	1.36	66.38	0.23	2.02	2.58
3		30	10.12	12.12	09.54	1.89	66.08	0.25	2.26	3.08
4		40	10.28	11.63	10.17	1.53	66.21	0.18	2.18	3.04
5		50	11.53	11.58	10.55	2.67	63.50	0.17	2.21	3.67
6		60	12.57	11.05	10.61	3.82	61.78	0.17	2.32	4.23
7	0.40	10	08.24	15.61	07.54	1.08	67.21	0.32	2.24	2.31
8		20	09.21	15.22	08.62	1.59	65.12	0.24	2.12	2.75
9		30	10.52	14.17	08.79	1.32	65.00	0.20	2.24	2.82
10		40	11.12	12.83	09.53	2.54	63.77	0.21	2.68	3.44
11		50	10.91	11.69	10.46	2.50	64.25	0.19	2.52	3.52
12		60	12.68	11.83	10.57	3.60	61.14	0.18	2.69	4.16

Table 1: Gas composition and energy content of product gas during coir pitch gasification [12]

Sr. No.	ER	Time Minute	CO %	CO_2 %	H_2%	CH_4%	N_2%	O_2%	Gas Yield Nm³/Kg	H.H.VNm³
1	0.30	10	10.54	15.24	6.18	1.04	66.81	0.19	1.86	2.40
2		20	11.26	14.31	7.54	1.25	65.47	0.17	2.14	2.73
3		30	10.12	12.87	6.09	1.49	69.23	0.20	1.79	2.51
4		40	14.67	12.19	7.46	2.88	62.67	0.13	2.18	3.75
5		50	15.42	11.68	8.59	3.21	61.00	0.10	2.25	4.10
6		60	19.55	10.21	8.62	3.24	58.33	0.05	2.31	4.61
7	0.40	10	10.11	16.28	5.54	1.08	66.68	0.31	2.23	2.29

8		20	09.87	15.44	6.65	1.27	65.53	0.24	2.37	2.47
9		30	10.53	13.89	6.78	1.66	65.98	0.16	2.31	2.71
10		40	12.64	12.17	6.59	2.26	66.14	0.20	2.40	3.16
11		50	14.78	10.66	7.42	2.01	65.06	0.07	2.56	3.43
12		60	16.13	10.68	7.77	2.78	62.58	0.06	2.57	3.92

Table 2: Gas composition and energy content of product gas during rise husk gasification [12]

Sr. No.	**ER**	**Time Minute**	**CO %**	**CO_2 %**	**H_2%**	**CH_4%**	**N_2%**	**O_2%**	**Gas Yield Nm^3/Kg**	**H.H.V Nm^3**
1	0.30	10	14.23	14.51	6.54	1.02	63.58	0.12	2.42	2.88
2		20	15.19	12.62	7.54	1.81	62.76	0.08	2.51	3.42
3		30	16.28	13.89	7.98	2.04	59.75	0.06	2.43	3.69
4		40	15.61	12.18	8.23	1.60	62.31	0.07	2.52	3.47
5		50	17.38	11.96	9.98	2.45	58.05	0.18	2.71	4.21
6		60	17.54	10.78	10.14	3.21	58.29	0.04	2.64	4.54
7	0.40	10	13.55	15.31	5.59	1.06	64.31	0.18	2.84	2.70
8		20	14.41	14.87	6.78	1.17	62.70	0.07	2.92	2.99
9		30	15.82	13.25	7.69	1.24	61.91	0.09	2.89	3.29
10		40	15.67	12.55	7.82	1.80	62.12	0.04	3.01	3.50
11		50	16.32	11.16	8.12	2.14	62.14	0.12	3.15	3.75
12		60	17.73	11.87	9.35	2.62	58.29	0.14	3.21	4.24

Table 3: Gas composition and energy content of product gas during saw dustgasification [12]

VI. CONCLUSION

Following are major conclusions on the basis of above study

- higher equivalence ratios favored more conversion of carbon
- Compared to air gasification, steam gasification produces a higher energy content producer gas.
- Combustible gas concentration increased with increases in Bed temperature
- Heating Value of Produced gas was increased with increased in equivalence ratio
- During the gasification of wood in a fixed bed Gasifier, the gasification rate increased, when the particle size was decreased from 19.05 to 5.00 mm.

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