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Study of Circulating Fluidized Bed Gasifier

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Abstract:
Indian coal was used for the present work. Temperature during gasification was varied with 800 to 900°C and Inlet air temperature was varied within the 100to 300 °C. Engineering Equation solver [EES] simulation was carried out for optimization of process parameters. EES simulation and pilot experimental data were found to similar in the some cases and there is +-10% difference in both simulation and experimental data. Effect of gasifier temperature, effect of the gasifier pressure, and effect of coal feed rate, effect of circulation rate on Gas composition and cold gas efficiency, syngas GCV has been studied by using EES and checked with experimental data. Solid circulation rate varies between 1 to 3 times of the coal feed rate and check the Syngas concentration by using EES. General heat and material of gasifier balance are describes in this paper. General heat and component balance also described in the paper.

Keywords: CFBG, Gasifier, Chemical reactions, Heat and material balance, Hydrodynamics, EES simulation.

I. INTRODUCTION

Gasification is the technique to convert the solid fuel (like coal and biomass) by the series of thermo chemical process like pyrolysis, oxidation and reduction into the Syngas/producer gas and which can be further converted into valuable products like power, chemicals and replacement of Furnace oil etc. The Syngas containing the major constituents as carbon monoxide (CO), hydrogen (H2), methane (Ch4), carbon dioxide (CO2) and nitrogen (N2). The gasification process occurs in presence of steam and air at temperature in between 800 to 950 °C. Gasification is a partially oxidation of carbogenius material.
Gasification also provides an opportunity to control and reduce gaseous pollutant emissions, and a lowest cost approach to concentrate the carbon dioxide at high pressure to facilitate sequestration. In fluidized bed there is good mixing over the reactor and maintained the temperature, Good heat and mass transfer of oxidants and fuel also good distribution of the material in the bed.

1.1 Types of Gasifier

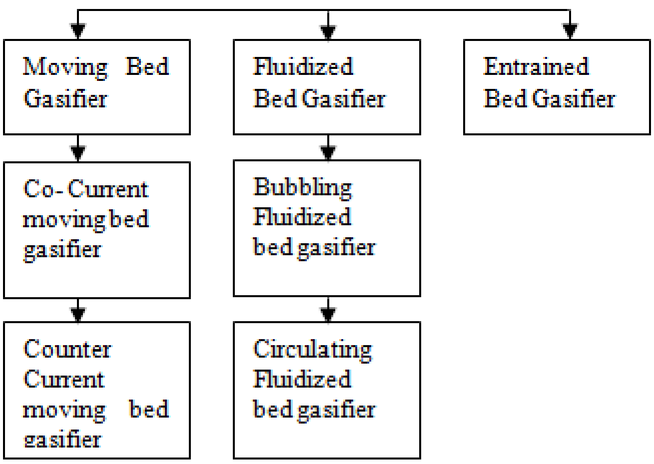


Figure 1.1 Types of gasifier reactor

1.2 Reactions involved in the gasification

Drying Zone: In drying zone main operation is to remove the moisture content from the feed material. In General this zone occupies more volume of a gasifier.

Pyrolysis Zone
In that zone the partial oxidation of carbon by using steam is carried out
$C + H_2O = H_2 + CO$

Reduction Zone
In reduction zone the carbon dioxide present in the gasifier reacts with char to produce CO
According to the following endothermic reaction, known as the Boudouard Reaction
$CO_2 + C = 2CO$

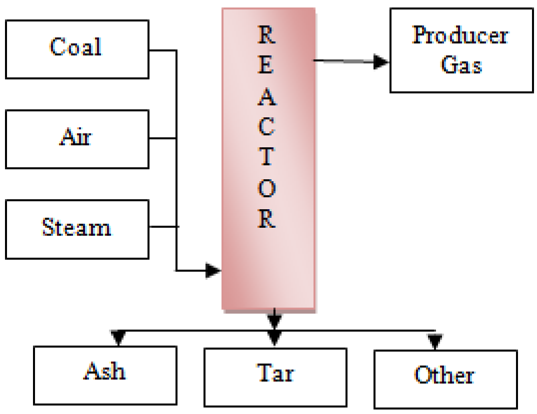
Oxidation/combustion zone
Shift conversion and Methanation are two major reactions taking place in this zone. The heating Value of hydrogen is higher than that of carbon monoxide. Therefore, the reduction of steam by Carbon monoxide to produce hydrogen is a highly desirable reaction.

$CO + H_2O = CO_2 + H_2$

Methane also forms in the gasifier through the following overall reaction:

$C + 2H_2 = CH_4$

1.3 Gasifier Heat and Material balance



The overall material and mass balance taking around the gasifier as follow

$$INPUT = OUTPUT - ACCUMULATION$$

General Material balance

$$INPUT\ MATERIAL\ FUEL = OUTPUT\ PRODUCT\ GAS - ACCUMULATION$$
$$= MOITURE\ FROM\ COAL + UNDECOMPOSED\ STYEAM$$

Hydrogen Balance

H from coal + H from moisture of coal + H from steam + H from moist air = H in tar + H in Producer gas.

Oxygen Balance

O from coal + O from moisture of coal + O2 from air + O from moist air + O from steam = O in tar + O in Producer gas.

Carbon Balance

C from coal = C in Ashes + C in tar + C in soot + C in Producer gas

Heat balance

$Q = m^* C_p {}^*\Delta T$

Where
Q = Heat energy
M = Mass flow
Cp =Specific heat
Δt = Temperature Difference

Total Heat input to the Gasifier = Heat input given from coal + Heat input given from the hot air + Heat input given from the steam.

Heat input given from coal
$= m[\text{coal flow}] * Cp * T[\text{coal in temp} - \text{coal outlet temp}]$
Total heat output = Syngas heat energy + Heat loss

1.4 Hydrodynamic

1.4.1 Minimum fluidization velocity (Umf)
Fluidization state starts when drag force by upward moving gas equal to the weight of particle or the velocity at which the solid gravitational force on solid is balanced by drag force action on it this force velocity is known as minimum fluidization velocity.

$$\mathbf{Umf} = \frac{dp\wedge 2(\rho s - \rho g)}{150\mu} * g * \frac{\mathcal{E}mf^3 * \phi s\wedge 2}{1 - \mathcal{E}mf}$$

1.4.2 Chocking velocity (UCH)
The term chocking has been generally used to describe a phenomenon which occurs when there is an abrupt change in the behavior of a gas solid conveying system. Riser in which solid particles are being conveyed at a given rate and gas velocity is gradually reduced this eventually change in the phenomenon is chocking. Chocking has been found to depend on the properties of gas and solid particles, size and geometry of the column.

1.4.3 Slugging velocity (UC)
If the bed is small in cross-section and deep, the bubble may increase to a size of about the diameter of the bed. The bubble passes through the bed as slug. This is known as slugging and there is a large fluctuation of pressure drop across the bed.

1.4.4 Terminal Velocity (Ut)
When an object which is falling under the influence of gravity or subject to some other constant driving force is subject to a resistance or drag force which increases with velocity, it will ultimately reach a maximum velocity where the drag force equals the driving force. This final, constant velocity of motion is called a "terminal velocity".

Terminal velocity is calculated by using the following formulae

$$\mathbf{Ut} = [\frac{4 * dp^2 * (\rho s - \rho g)}{3\rho g\ Cd} * g]\wedge 0.5$$

II. MATERIAL AND METHOD

2.1 Experimental setup
Coal is feeding with calibrated screw feeder. Air and steam injected from the bottom (Plenum) of the gasifier. Syngas generated from the reactor passed through the first cyclone, to removes the unburnt and this leg is reconnected to gasifier. Loop seal is provided for recirculation the unburnt particles. After this the gas is passed through the second cyclone to removes the ash. This gas is combusted in the combustor.

2.2 Experimental Process

Step-01: Heating of refractory and bed material
Electric heaters were used to heat the air and this heated air is fed in to gasifier to heating refractory. Refractory and bed material heated up to the coal ignition temperature, coal ignition temperature is around 300˚C by using electric heaters.

Step-02: Coal Combustion
When temperature of bed material reached up to ignition temperature (500˚C) of coal, then we were starting the combustion by adding coal batch wise.

Step-03: Gasification
Gasification started by coal adding continuously at constant rate and adjusted the air depending on ER.

Step-04: Sampling

Sample was taken during gasification for chromatography analysis.

Step-05: Shutdown and cooling of the gasifier
2.3 Coal Properties and Bed material
Proximate analysis indicates the percentage by weight of the Fixed Carbon, Volatiles, Ash, and Moisture Content in coal. The amounts of fixed carbon and volatile combustible matter directly contribute to the heating value of coal. Fixed carbon acts as a main heat generator during burning. High volatile matter content indicates easy ignition of fuel. The ash content is important in the design of the furnace grate, combustion volume, pollution control equipment and ash handling systems of a furnace. The ultimate analysis indicates the various elemental chemical constituents such as Carbon, Hydrogen, Oxygen, Sulphur, etc. It is useful in determining the quantity of air required for combustion and the volume and composition of the combustion gases.

Table.i. Coal proximate analysis

	Dry wt %
Moisture	11.9
Ash	26.87
Volatile	27.93
Fixed Carbon	33.3

Table .2. Coal ultimate analysis

	Dry wt %
Carbon	51.45
Hydrogen	3.86
Nitrogen	0.6
Sulfur	0.25
Oxygen	13.24
Ash	30.50

Gross Calorific Value 4959 kcal/kg

Table. 3. Bulk density analysis

	Kg/m3
Coal	705
Bed material	1750

Particle size distribution of Bed material [PSD]

Sr. No	Screen size Mm	Wt Gm	Mass fraction	Avg screen size Dpi	Xi/Dpi
1	1	13	0.01310	1	0.01310
2	0.841	103.7	0.1045	0.9205	0.1135
3	0.595	181	0.1824	0.718	0.2541
4	0.5	210	0.2118	0.5475	0.3869
5	0.3	337	0.3399	0.4	0.8499
6	0.21	64.4	0.0649	0.255	0.2546
7	0.105	18.4	0.0185	0.1575	0.1177
8	0.074	32.2	0.0324	0.089	0.3627
9	0	31.8	0.0320	0.037	0.8665
	Total	991.8		∑Xi/Dpi	3.2195

Mean particle size = 1/∑Xi/Dpi =1/3.2495=0.3

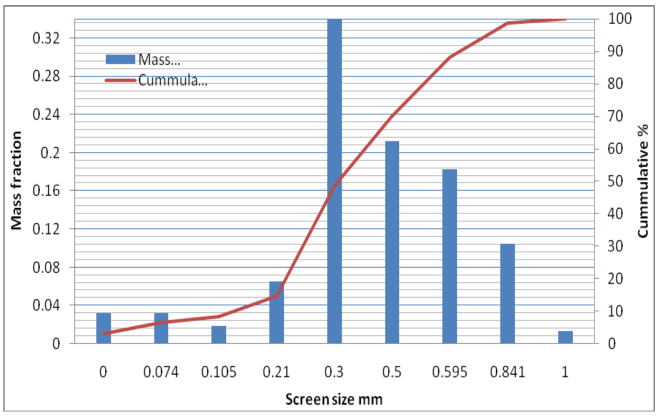


Figure.2.1 Particle size distribution of bed material (Olivine) Mean particle size of bed material 0.3 mm

III. RESULT AND DISCUSSION

3.1 Experimental results

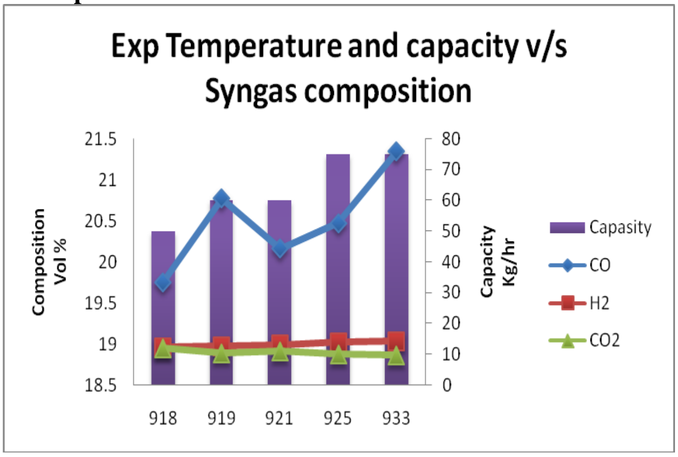


Figure.3.1.1 Effect of gasifier temperature and coal capacity on syngas composition

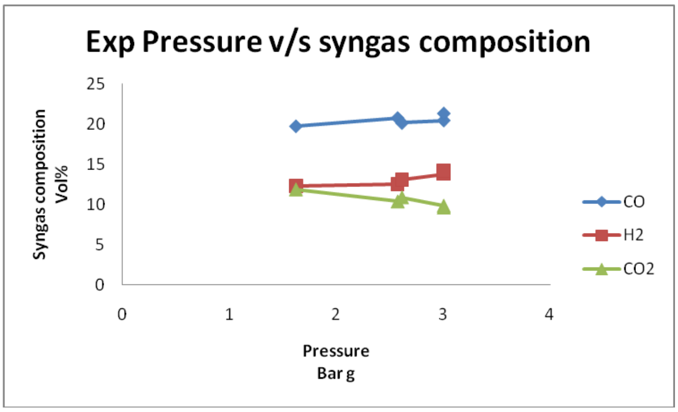


Figure.3.1.2 Effect of gasifier pressure on syngas composition

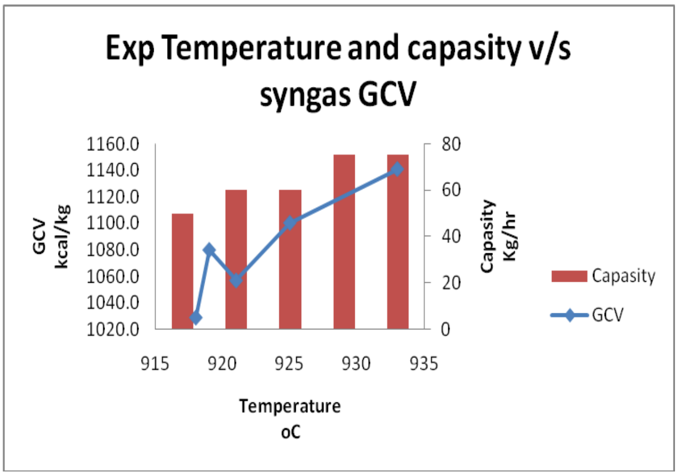


Figure 3.1.3 Effect of gasifier temperature and coal capacity on GCV

3.2 EES results

Modeling is an important means for scale up of a gasifier. It also helps the design of a unit based on results obtained from another gasifier operating on different feedstock. A good model will help identify the sensitivity of the performance of a gasifier to variation in the different operating and design parameters. The designer can speculate the effect of many parameters even without any experimental data on them. The model developed generally belong to one of the following three categories

1] Kinetic 2] Equilibrium

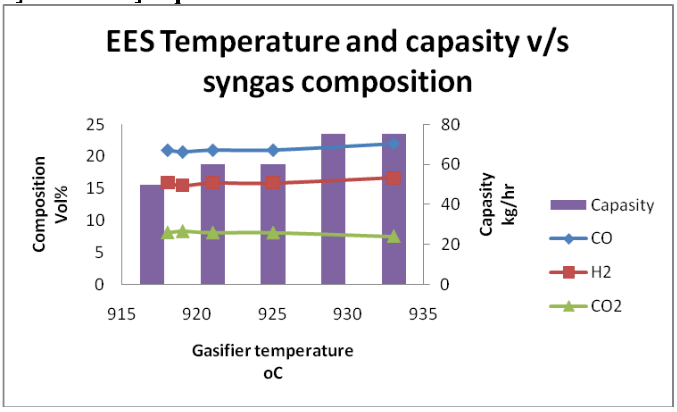


Figure 3.2.1 Effect of gasifier temperature and coal capacity on syngas composition

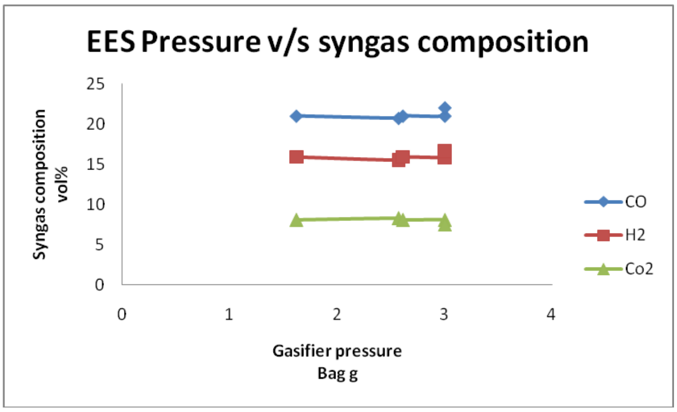


Figure3.2.2 Effect of gasifier pressure on syngas composition

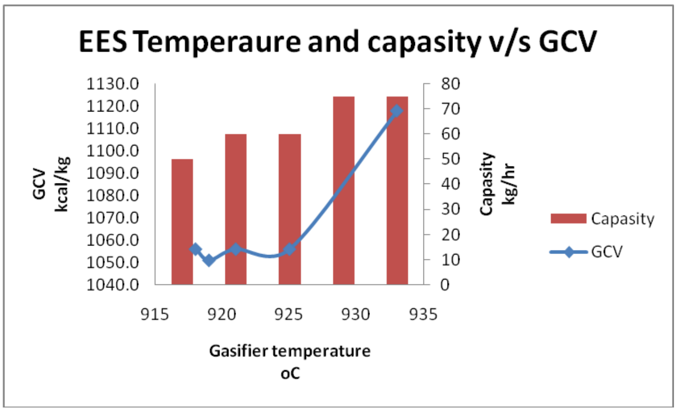


Figure 3.2.3 Effect of gasifier temperature and coal capacity on GCV.

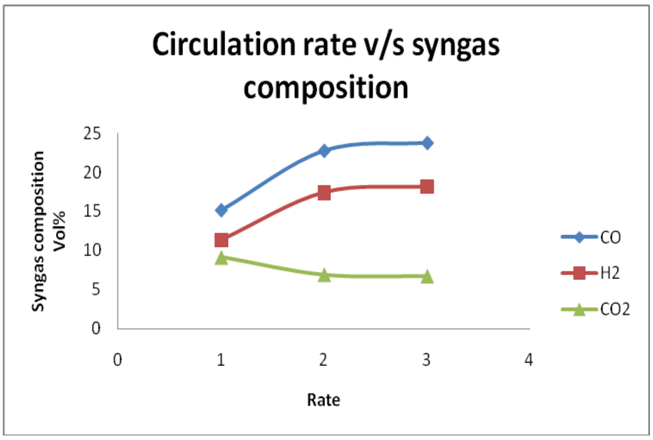


Figure 3.2.4 Effect of solid circulation rate on syngas composition

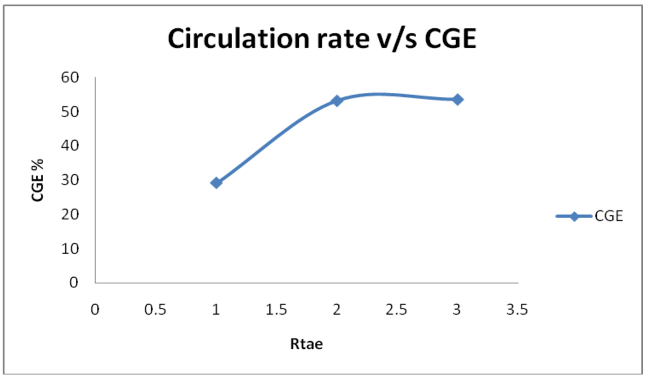


Figure 3.2.5 Effect of solid circulation rate on CGE

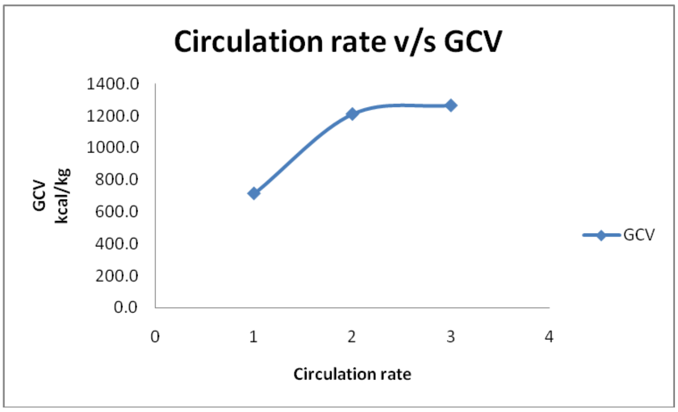


Figure 3.2.6 Effect of solid circulation rate on GCV.

3.3.1 Effect of Gasifier temperature

EES results are also shows that the Gasifier temperature improves the syngas composition. CO (20 to 22vol %) concentration and H2 (15 to 17 vol %) concentrations increases with increasing the gasifier temperature. Methane also varies from 1 to 1.2 vol % by varying gasifier temperature. Gross calorific value of syngas raised from 1000 to 1150 kcal/kg by raising the gasifier temperature.CGE increases 40 to 51 % when gasifier temperature varies between 900 to 950˚C.

3.3.2 Effect of Gasifier pressure on the syngas composition

In simulation also positive effect on the gasifier performance, while increasing the pressure of gasifier. CO concentration increases 20 to 22 vol % and H2 15 to 17 vol % concentration increases when increasing the gasifier pressure.

3.3.3 Effect of Coal capacity on the syngas composition

In simulation when increases the coal feed capacity then we found that the CO (20 to 22 vol %) and H (15 to 17 vol %) concentration increase, GCV of syngas increases 1000 to 1150 kcal/kg, also increases the Syngas CGE in between 50 to 50.80%.

3.3.4 Effect of solid circulation rate on Syngas composition

Solid circulation rate improves the gasification efficiency. From data which are generated from the EES, Solid circulation rate increases 1 to 3 times we found that the CO (15 to 24) concentration increases and also H2 (11 to 18) concentration increases. Increases CGE % (30 to 60) and GCV (700 to 1200 kcal/kg) by increasing the solid circulation rate.

IV. CONCLUSION

This present study shows that the gasifier performance is depending on the gasifier temperature, pressure and coal flow rate. Simulation and experimental results are similar in some cases and - + 10% difference in other. Solid circulation rate also improves the gasifier performance.

V. REFFERENCE

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