Research Paper

STUDY OF FLUIDIZED BED GASIFIER

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ABSTRACT

Coal is the major source of energy for India and it contributes to more than 42% of total energy consumption. The energy dependence on coal will also continue in long term future. Hence it is important to study coal and technologies that generate energy utilizing coal. India has around 285.86 billion tonnes of coal reserves but only 118 billion tonnes of it are proven resource. India's current domestic production of coal is 0.55 billion tonnes and with this it is expected that the proven resource will last for only 200 years more with current consumption rate. Hence it is required to optimize the usage of coal and make the technologies more efficient and environment friendly. Coal gasification is one such technology which has potential to enhance the efficiency of the current power generation technology by atleast 10-15 % and reduce the pollutant emission by atleast by 15%. Hence coal gasification is important technology which should be developed for usage of Indian coal.

1. INTRODUCTION:

Gasification converts solid fuel into syngas/producer gas (CO, H_2 and CH_4). Gasification works under sub stiochiometric O_2 condition along with steam as reactant. The syngas need to clean to remove pollutants like H_2S, NH_3 and dust. After cleaning the syngas has many applications to generate power, transportation fuels, Fertilizers, Chemicals, H_2 etc.

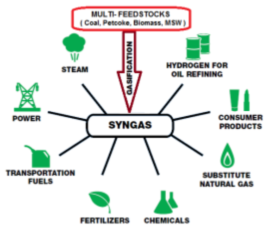


Figure 1 : Polygeneration utility of syngas

Hence polygeneration nature of the syngas utilization makes gasification more attractive option for utilization of coal.

1.1 Types of gasifiers

Worldwide many types of gasification technologies are developed and they are categorized into following main types:

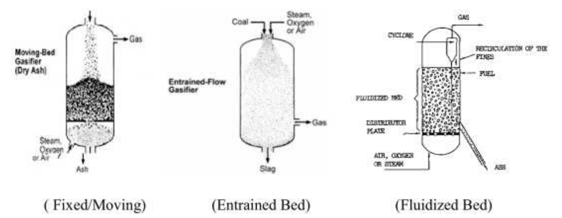


Figure 2 : Types of gasifier

- ***Moving bed***

Fixed or Moving Bed Gasifier its having two types Updraft Gasifier & Downdraft Gasifier. Moving bed gasifiers are countercurrent flow reactors in which the coal enters at the top of the reactor and air or oxygen enters at the bottom. As the coal slowly moves down through the reactor, it is gasified and the remaining ash drops out of the bottom of the reactor. Because of the countercurrent flow arrangement, the heat of reaction from the gasification reactions serves to pre-heat the coal before it enters the gasification reaction zone. Consequently, the temperature of the syngas exiting the gasifier is significantly lower than the temperature needed for complete conversion of the coal.

- ***Entrained bed***

Finely-ground coal is injected in co-current flow with the oxidant. The coal rapidly heats up and reacts with the oxidant. The residence time of an entrained flow gasifier is on the order of seconds or tens of seconds. Because of the short residence time, entrained flow gasifiers must operate at high temperatures to achieve high carbon conversion. Consequently, most entrained flow gasifiers use oxygen rather than air and operate above the slagging temperature of the coal. There are many international players demonstrated this technology at large commercial scales for entrained bed gasifier mostly for petcoke and anthracite coal.

- ***Fluidized bed***

Fluidized bed gasifiers are similar to fluidized bed boilers except they operate at sub stiochiometric oxidant condition and may be at high pressure. Fluidized bed gasifier has a bed made up of sand or crushed refractory which acts as a heat sink media to control the bed temperature. This bed is also called as dense phase of gasifier where the solid fuel is injected. The reactants like O_2 and steam are pre-mixed and injected from a distributor plate below the dense bed. This creates good amount of mixing of solid and hence uniform temperature in the bed. There is no heat removal facility as the heat generated during the oxidation reactions are absorbed by the endothermic gasification reactions. There are two primary types of gasifier viz: bubbling bed and circulating bed. The velocity at which the solids gravitational force on solid is balanced by drag force acting on it. This condition is called as minimum fluidization velocity (U_{mf}). The ratio of superficial velocity to U_{mf} is called as fluidization index. The bubbling beds are design with 2-10 as fluidization index and circulating beds have 20-40 as fluidization index. Circulating bed gasifier operates superficial velocity higher than the terminal settling velocity, and needs a cyclone separator for collecting back the elutriated bed material back to the gasifier. This type of gasifier increases the rate of gasification and is suitable for large scale power generations. India has done pioneering work on bubbling bed gasifier for Indian high ash coal. The international players have demonstrated the fluidized bed gasifier technology at commercial scale for high rank coal but no demonstration is available for high ash coal.

2. MOTIVATION OF PRESENT WORK

Fluidized bed reactors have been commonly used for gasification of solid carbon fuels such as coal, char, charcoal, wood, peat & the like with steam & air or oxygen, to produce useful synthesis gas (Syngas).

These fluidization technology has been extensively applied to various chemical processes. It provides better heat & mass transfer between the fluid & solid compared to conventional packed or moving bed unit operations. Some common industrial processes using fluidization technology include drying, catalytic cracking, chemical synthesis, adsorption-desorption, gasification, pyrolysis, granulation, calcinations, combustion, coating, bioreactor, polymerization, ore beneficiation & coking. This article summarizes the basic concepts of fluidized bed technology & provides a useful collection of equations for gas solid systems

So we select Fluidization process for the study of Fluidized Bed Gasifier here particulate matter or bulk solids are poured into a vessel, the particles arranged themselves into a random configuration to form a fixed bed. The space between particles becomes filled with ambient gas & forms a network of interconnected voids. The volume occupied by the packed bed is always greater than the volume of particulate material itself. The ratio of void volume to the total volume of packed bed is called voidage. Sometimes "porosity" is used to describe voidage of packed beds, but this should not be confused with the porosity within the particles.

When a fluid (gas or liquid) is introduced uniformly at the bottom of packed or fixed bed, it percolates upwards through the interstitial voids. The drag of the gas of the particles is counteracted by the pressure drop across the bed or weight of the bed divided by cross sectional area .The packing configuration of the bed remains unaltered as the fluid finds the tortuous path through the packing in the upward direction.

According to this principle we motivated to select the process Bubbling Bed Gasifier & Circulating Bed Gasifier which based on this. In Bubbling Bed Gasifier we will concentrate to study Minimum Fluidization velocity(Umf),Minimum Bubbling velocity(Umb).In Circulating Bed Gasifier here we study the Circulation studies to calculate Circulation rate or Recycle Rate in circulation study by taking different kinds of material like Sand (223 micron & 150 micron size)& also Fly Ash. We analyze the different design modifications of Recycle loop for the purpose of increasing efficiency of Circulation Study.

3. CIRCULATION STUDY ON 223 MICRON SAND :

3.1 Density of Sand Calculation :

Aim:- To find the true density and tap density of given samples of sand.

Apparatus used:-Weighing machine (digital), filter paper, specific gravity bottle (50ml), measuring cylinder, dryer, funnel, conical flask, spatula.

Chemicals used:-sand samples (3 nos.), water

Procedure:-

- Weigh approximately 5g of sand of sand from the small sample (223 µm) using a weighing balance.
- Pour it into a measuring cylinder and gently tap the cylinder.
- Find the volume of sand using the cylinder.
- Tap density=mass/volume occupied in measuring cylinder.
- Now weigh the empty specific gravity bottle.
- Pour the sand into the specific gravity bottle.
- Weigh the bottle again.
- Fill water in the specific gravity bottle using funnel, conical flask. Wipe it with filter paper.
- Weigh the bottle now.
- Clean the bottle until the sand is completely washed off.
- Now fill the bottle completely with water.
- Measure the weight of the bottle.
- Density of water=[(mass of water + bottle) – (mass of bottle)]/volume of water
- Mass of sand= [mass of bottle + sand)-(mass of bottle)]
- Mass of water=[(mass of water + bottle + sand)-(mass of bottle + sand)]
- Volume of water=mass of water/density of water.
- Volume of sand= 50ml- volume of water
- Density of sand= mass of sand/volume of sand.

Observation and results Table:

	Small	Units	Medium	Units	Large	Units
Mass of Bottle	31.264	G	31.264	g	31.264	G
Mass of Bottle+Sand	36.2676	G	36.2796	g	36.2944	G
Mass of water+ Bottle +sand	84.2921	G	84.2277	g	84.2544	G
Mass of water	48.0245	G	47.9481	g	47.96	G
Mass of Water+Bottle	81.2033	G	81.2033	g	81.2033	G
Volume of Bottle	50	Ml	50	ml	50	Ml
Density of Water	0.99996	g/cc	0.9984	g/cc	0.9996	g/cc
Volume of Water	48.08287	Ml	48.00638	ml	48.01829	Ml
Volume of Sand	1.917127	Ml	1.99362	ml	1.981706	Ml
Density of sand	2.609947	g/cc	2.515825	g/cc	2.538419	g/cc
Density of Sand	2609.947	kg/m^3	2515.825	kg/m^3	2538.419	kg/m^3

Results:- The true density of sand is found to be

- 2609.947kg/m^3 for small sample.
- 2515.825kg/m^3 for small sample.
- 2538.419kg/m^3 for small sample.

The tap density is found to be:

- 1111.11kg/m^3
- 1097kg/m^3
- 1136kg/m^3

3.2 Methods of Operation :-

i) First fill the Gasifier Bed with Sand of 223 micron size at 600 mm Height.

ii) Then start main valve from Dryer & also start the Valve of Blower which gives the air to the Gasifier Bed Material for fluidization Purpose.

iii) At the same time don't operate globe valve.

iv) Before Blower should operate start the loop seal flow by using 'C' line, to avoid the full material bed formation in recycle pipe.

v) Flow of Blower adjust according to your corresponding gasifier velocity; simultaneously operate the Rotameter by adjusting the flow rate which provides air for recirculation from recycle pipe towards the gasifier bed.

vi) Then adjust the flow by using data data logger panel with the help of Blower main valve fluidization of sand would be occurs then simultaneously with this start the loop seal & adjust the flow rate to establish the certain bed height in recycle pipe then record the data for the accurate measurement of-:

- PT (Pressure Transmitter) =0-2000 mm of H_2O
- DPT-5 (Loop seal Pressure Drop)= 0-3000 mm of H_2O
- DPT-1 (Orifice Pressure Drop) = 0-200 mm of H_2O
- DPT-4 (Plenum Pressure Drop) = 0-1000 mm of H_2O
- T ^{0}C (Temperature) = 0-400^{0}C

vii) The PT, DPT-5, DPT-1,DPT-4 & RTD located at their respective location.
viii) Take the above readings of respective pressure drops, Temprature & Pressure Transmitter readings.
ix) If we record the above data then for that data record recycle rate by using following procedure

- If we record the above data then for that we record the recycle rate. Here we first mark the exact line which indicates bed of height 1.5 to 2.0 meter once that height should be reached we mark this level of 2m height by Red or Green cello tape & immediately we start the Purging which is provide to Recycle Loop by Using Rotameter for Recirculation purpose which is adjusted from 2 to 20 m^3/hr for 6 to 30 mm of H_2O respectively. Now for 2 m^3/hr Recycle loop flow rate Rotameter material bed which is formed in Recycle pipe slowly starts to moves down through recycle pipe & finally material came into Recycle loop which avoids backflow of material towards the Recycle pipe again.
- We record the height of 2 meter, Once we start the Rotameter for recirculation then simultaneously start stop watch & record the how time will required to reach the bottom of recycle pipe to the sand material by using this time & corresponding height relation we will calculate the recycle rate.
- Repeat this Procedure for two times i.e we will get 6 readings of recycle rate for 6 mm of H_2O at which gasifier velocity should be 1.94 m/s. By using same procedure for 8,10,15,20, 25 & 30 mm of H_2O Pressure we will record their corresponding recycle rate.
- This above overall procedure i.e Fluidization of material in Gasifier Bed at certain flowrate, gasifier velocity; then these material comes into cyclone where separation of solid particles from gas stream recycled that material again towards the Gasifier bed through the recycle pipe & recycle loop & these overall procedure is called as Circulation studies.

There are no. of experiments were done for circulation studies on Sand (223 micron). The Tabular form,
Graphical Representation & Recycle Rate calculation Experiments are as follows-:

3.3 Experiments on Sand (223 micron) for Circulation studies:-

3.3.1 For Orifice Pressure Drop 6 mm of H_2O:-

Basic Data:-

a) Material = Sand
b) Size of Sand Particles=223 micron
c) Tap/Bulk Density= 1100 Kg/m^3
d) True Density = 2600 Kg/m^3
e) Bed Height = 600 mm
f) Orifice Pressure Drop = 6 mm H_2O
g) Q (m3/hr) =119.54 m^3/hr
h) Q actual = 123.33 m^3/hr
i) Vo (Orifice) =1.94 m/s
j) Umf = 0.051 m/s
k) Ut = 1.49 m/s
l) Loop Seal Flow Rate= 2 m^3/hr
m) Loop seal velocity-: Q= Area x Velocity
= [pi/4] x d^2x velocity
n) UL (Loop Velocity) =0.03145 m/s

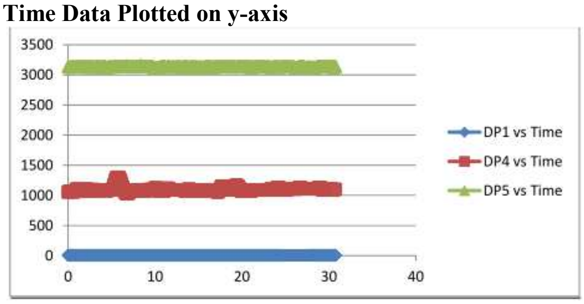
3.3.2 Notifications-:

a) Temprature=0-400 degree centigrade
b) PT-1=PT-1=0-2000 mm of H_2O
c) Loop Seal(DPT-5)=0-3000 mm of H_2O
d) Orifice=DPT-1=0-200 mm of H_2O
e) Plenum(Dpt-4)=0-1000 mm of H_2O

3.3.2 Graphical Presentation of Pressure Drop Readings:-

Pressure Drop (DP1, DP4 & DP5) mm of H_2O vs Time microseconds

Pressure Drop Data Plotted on X-axis
Time Data Plotted on y-axis



From above graph we will get Average Pressure Drop Data:-
Average DP1= 5.75 mm of H_2O
Average DP4= 978.37 mm of H_2O
Average DP5=3125.39 mm of H_2O

3.3.3. Recycle Rate Calculation :-

No. of measurements	Sand Density	1100	kg/m3			
	height [m]	time[sec]	volume of pipe[m3]	Vol flow rate of solids [m³/s]	mass flowrate of solids [kg/hr]	flux of solids[kg/m²/s]
1	0.4	14.53	0.00079	0.194	213.94	30.28
2	0.45	15.53	0.00088	0.205	225.19	31.87
3	0.35	15.34	0.00069	0.161	177.32	25.10
4	0.4	14.04	0.00079	0.201282051	221.41	31.34
5	0.45	16.65	0.00088	0.190945946	210.04	29.73
6	0.35	14.94	0.00069	0.165512048	182.06	25.77
				Average=	**204.99**	**29.02**

3.3.4. Recycle Rate Calculation Method:-

1) Area of Recycle Pipe= $(\pi/4) \times d^2$
Where d=diameter of recycle pipe=50 mm
Area of Recycle Pipe=$(\pi/4) \times (50)^2 \times (10^{-3})^2$
= 0.0019634954 m^2

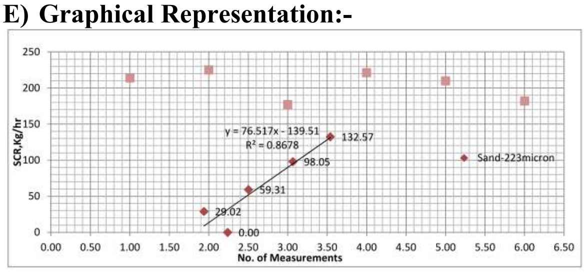
2)Volume of recycle Pipe=Area of Recycle pipe x Height
=0.0019634954 x 0.4
=0.00079 m^3

3) Volumetric Flow Rate=(Volume of Pipe)/(Time)
=(0.00079) x 14.53
=0.194 m^3/s

4) Recycle Rate or Mass Flow Rate of Solids= Density of Sand x Volumetric Flow Rate
=1100 x 0.194
=213.94Kg/hr

5) Flux Produced=(Recycle Rate)/(3600 x Area of Recycle Pipe)
=(213.94)/(3600 x 0.0019634954)
=30.26 Kg/(m^2.s)

E) Graphical Representation:-



Remaining Inventory in Gasifier Bed = 400 mm
Downcomer Height of Material In Recycle Pipe = 530 mm

4. CONCLUSION :-

Circulation Study On Sand (223 micron size Particles) with constant bed height 600 mm, constant density 1100 Kg/m3,Constant fluidization velocity 0.051 m/s, Constant terminal settling velocity 1.49 m/s & constant Loop Seal Velocity 0.03145 m/s are shows the following results:-

1) From above no. of experiments 1st we concluded that as we increase the Orifice flow rate for fluidization with respective DPT then Gasifier Velocity goes on increases which are
2) From the graph of Pressure drop we also concluded that as we increase the Orifice flow rate with corresponding Orifice Pressure Drop we will get the average differential pressure of Orifice & Plenum by plotting the data of Orifice, Plenum & Loop Seal Pressure drop vs Time which shows that as we increase the flow rate of Orifice then Avarage Pressure Drop of Orifice, Plenum & Loop Seal also goes on increases which are as follows:-
3) In Circulation Study experiment we use the Loop Seal for fine recirculation of sand particles from recycle pipe towards the gasifier bed & also it is used for to avoid the backflow of sand Particles towards the recycle pipe. As we increase the flow rate of loop seal for fine recirculation then differential pressure of Loop seal & Corresponding Loop Seal Velocity goes on increases with loop seal flow rate. Which are as follows:-
4) From above no. of experiments we also concluded that at the constant bed height 600 mm as we increase the Orifice flow rate, Orifice, Plenum & Loop Seal- Pressure drop & loop seal flow rate then Recycle Rate or Mass flow Rate also goes on increases. And due to increasing Recycle Rate Flux of Sand Particles also goes on increases.(From the graph of Solid Circulation Rate vs No. of Measurements i.e Experiments).

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