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Tar and spm reduction in producer gas by using different catalysts for fluidized bed gasifier

[1]Mayur B Patel, [2]Jay M Patel

[1]M.E. Student, [2]Assistant Professor
[1] Mechanical Engineering Department,
[1]Mahatma Gandhi Institute of Technical Education & Research Centre, Navsari, India

***Abstract*— Gasification is the process in which conversion of biomass fuel (coal, petcock, munsipal solid waste) into syngas or producer gas that content CO, CO_2, H_2, CH_4, H_2O, NH_3. In the present study of gasification fluidized bed gasifier chose because of it is more compact then other and also they provide better mixing, uniform temperature and ability to handle low quality fuels. In present study Investigate the effect of addition of two naturally occurring catalysts, namely dolomite and olivine in different proportion (10-60 wt.%)separately in the bed of sand along with self –sustaining charcoal heating in order to determine the most suitable composition of catalysts in both the cases. Most suitable equivalence ratio is 0.3 and 0.35 Dolomite provided 45 and 50% while olivine provided comparatively less41 and 44% tar + SPM reduction at the ER of 0.3 and 0.33, respectively. However, olivine generated less fine particles and consumed 66% less energy for bed heating than dolomite. Improvement in the carbon conversion by 5–7% were obtained with the addition of catalysts.**

***Index Terms*— saw dust, dolomite, olivine. sand, TAR +SPM, gasification.**

Introduction

With the vast and diverse industrialization in the 21st century, the demand for fuel is increasing rapidly. Biomass after the thermochemical conversion process based on the application can be converted into energy sources like electricity, liquid fuels and gaseous fuels at present biomass satisfies10–14% of energy demand across the globe Biomass gasification involve conversion of biomass into a gaseous fuel called producer gas or syngas. Based on the type of bed gasifiers are classified into: moving bed (updraft and down draft), fluidized bed (bubbling, circulating and twin or dual), entrained bed and spouted bed Moving bed gasifiers has certain disadvantages such as, updraft gasifiers produces gas with quite high tar content around 10–150 g/m3 while downdraft gasifiers can handle only selected and pre-treated fuels(fuel with low ash content) because of their higher operating temperatures (1100–1200◦C). This limitation of the moving bed gasifiers can be overcome by the utilization of fluidized bed gasifiers (FBG). FBG are quite popular because of their ability to handle wide variety of fuels and higher heat transfer rates inside the reactor because of the fluidizing nature of bed (Lasa et al., 2011). Recent developments involve entrained bed gasifiers in which fuelin powder form is injected along with the gasification agent. They are generally operated around 1400◦C temperature and 20–70 bar pressure Spouted bed gasifiers also have been successfully utilized for the gasification of saw dust and pow-dared coals of different grades Utilization of the entrained and spouted bed for biomass gasification is limited because of their complex con-struct ion and ability to utilize biomass only in powder form..

I. LITERATURE REVIEW

Pradip k. Chatterjee et.al. [1] Energy generation from fluidized bed gasification of rice husk**"**, they have work on an experimental study of biomass gasification is conducted using a laboratory scale bubbling fluidized bed gasifier the gas composition variation as a function of gasification temperature (T) and ER¼0.35. It is observed that higher temperature favored $H_2$and CO production. H_2 content increases from 9.2% to 12.3% and CO content increases from 12.8% to 14.5% by increasing the temperature from 750^0Cto 850^OC on the other hand, CH_4 content increases from 2.1% to 3.0%, while CO_2 content reduces with increase in gasification temperature.

Abanti.et.al [2] Gasifier performance and energy analysis for fluidized bed gasification of sugarcane bagasse" Experiments are carried out to determine the effects of different system parameters viz. gasification temperature, equivalence ratio, steam to biomass ratio and bed materials acting as catalyst for the production of hydrogen from sugarcane bagasse Thus it can be said that ER of 0.25, S/B ratio of 0.5 and use of 1:1 red mud and sand mixture for bed material is the optimum condition for sugarcane gasification as gasification temperature is reduced to 700^0C with satisfactory amount of H_2-yield which is very much cost effective. Further energy analysis report indicates gasification of sugarcane bagasse is eco-friendly and very much profitable.

Shamsuddin anis.et.al [5] Tar reduction in biomass producer gas via mechanical, catalytic and thermal methods: A review" Thermal and catalytic conversion methods are more attractive because of the complete destruction of tar. Besides, the methods have higher energy conversion efficiency all catalysts, nickel catalysts are the most effective to convert tar into fuel gas. Co-impregnation of nickel on natural catalysts (olivine, dolomite, and zeolite) can increase the stability to overcome the carbon deposition, as well as the cost is relatively inexpensive.

Jose corella.et.al [6] Olivine or Dolomite as In-Bed Additive in Biomass Gasification with Air in a Fluidized Bed: Which Is Better?" Four available and competitive additives have been compared in this work: a calcined dolomite) natural and sintered olivine's, and a Ni-olivine catalyst. They were tested under very similar experimental conditions in two small-scale pilot plants: the first pilot plant was based on a circulating fluidized bed (CFB) gasifier, and the second pilot plant was based on a bubbling fluidized-bed (BFB) gasifier It was concluded that both dolomite and olivine have one positive and one negative property. Dolomite was shown to be 1.40 times more effective for in-bed tar removal than the raw olivine, but it generated 4-6 times more particulates in the gasification gas than olivine. It was therefore impossible to say which additive was better.

II. EXPERIMENTAL SET UP

Fig 1., Description of Fluidized Bed Gasifier

The experimental set up which was developed is shown in Figure. The reactor was made of SS-316 seamless pipe and the total height of reactor is 1200 mm with an internal diameter of 100 mm. K-type thermocouples installed at 6 different sections of the FBG set-up to measure the temperatures of air inlet to the reactor (T1), static sand bed temperature (T2), fluidized bed temperature (T3), free board temperatures (T4 and T5) and gas temperature (T6). Sand bed was heated by approximately 1 kg of charcoal to eliminate the use of ceramic heater and hence reduce the electricity consumption (during initial start-up).10-15 mm diameter charcoal of 1 kg (330±10 gram at an interval of 10 minutes) was feeded from the screw feeder to increase uniform bed temperature up to 400^{0C} before starting of the operation. Before starting the feeding of the charcoal in the reactor, it was ignited in the improved biomass cook stove and air was blown for making them red hot charcoal. Purpose of this kind of heating arrangement is to make the FBG operation self-sufficient, sustainable and fit for rural agricultural applications. Biomass were delivered into the dense bed zone of the gasifier using a screw feeder. Air was blown by the blower and equally distributed by the distributor plate having 2 mm orifice diameter holes. It can be defined that a multi-perforated stainless-steel plate. Flow rate of air is measured by orifice type flow meter and air is control by air control valve. Cyclone separator which is the separate the gas and ash+spm. The producer gas was collected in the nitrogen balloon or rubber bladder for analysis from the outlet of cyclone separator through the gas cock, making the provision for sampling during the experiments. Composition of the producer gas determined by using the gas analyzer at GIDC CLG, abrama. Tar and SPM measurement is using the field sampler instrument by using Whatman filter paper.

III. DATA REDUCTION

1. Carbon conversion efficiency

It represents the ratio of volumetric percentage of carbonaceous gas species in the producer gas in comparison to solid carbon present in the biomass feedstock.

$$n_c = \frac{Y(CO\% + CH_4\,\% + CO_2\%) \times 12}{22.4 \times C\%} \times 100\%$$

Where Y = dry gas yield (Nm^3 /kg) and C % = mass percentage of carbon in the feedstock.

2. effectiveness of the gasification process is assessed in terms of the high heating value (HHV) of the producer gas

$$HHV = (H_2\% \times 30.52 + CO\% \times 30.18 + CH_4\% \times 95) \times 4.19$$

3. Dry gas yield

The nitrogen content of the biomass was ignored while calculating the dry gas yield, but the N2 content of air and producer gas, were considered during mass balance to obtain the dry gas yield.

$$Y = \frac{Q_a \times 0.79}{W_b\,(1 - X_{ash}) \times N_2\%}$$

Where, Q_a = flow rate of air (Nm^3 /h), W_b = mass flow rate of biomass (kg/h), X_{ash} = ash content in the feed, and $N_2\%$ = volumetric percentage of N_2 in the dry producer gas.

4. TAR + SPM COLLECTED IN FILTER PAPER

$$\text{TAR +SPM in filte} = \frac{\text{Final wegiht of filter paper (g)} - \text{Initial weight of filter paper(g)}}{\text{Gas flow rate}\left(\text{liter}/_{\text{min}}\right) \times \text{Time for sampling (min)} \times 10^{-3}}\ \text{g}/_{\text{m}^3}$$

V. RESULTS AND DISCUSSION

Effect of equivalence ratio

Equivalence ratio is an important parameter during the experiments as it controls the amount of heat that would release during the exothermic reactions. Smaller value of ER will provide lowered temperatures and gas with higher tar contents while higher value of ER will produce gas with lower heating values because of the cracking of hydrocarbons e.g. CH_4, tar and dilution of gas with N_2(etc. Initial experiments were carried for the sand bed at four different values of ER 0.25, 0.3, 0.35 and0.34. It was observed that at the ER 0.25 the bed temperature was around 650 ± 5◦C which provide gas with quite high tar + SPM con-tent around 12.1 g/m3. For higher ER (=0.40) bed temperature was around 750 ± 5◦C which resulted in the operational difficulties due to increase in the formation of clinkers as well as the bed agglomerates. It occurs due to high ash content in rice husk and its low ash melting points. Therefore; the ER 0.3 and 0.35 were selected for the further experiments.

. In order to maintain the ER of 0.3and 0.35 the air flow rate was kept constant at 9,1 m3/h and 10.6 m3/hr to keep the gas residence time same for both the cases and to maintain the fluidization of the bed in bubbling regime. However, saw dust feed rate was maintained at 5 kg/h , respectively. It was observed that as the ER increases the bed temperature as well as the gas outlet temperature increases this is because of reduction in the feeding rate resulted in the higher combustion. . With the increase in the ER from 0.3 to 0.35 the $H_2$and CO contenting the producer gas decreases while CO_2content in the producer gas increases because of increase in the oxidation reactions.. With the increase inER the CH_4content, tar + SPM content, and HHV of the producer gas reduced subsequently from 3.1 to 2.7%, 9.93 to 7.26 g/m3and 3.65to 3.38 MJ/m3due to increase in the cracking of hydrocarbons at higher temperatures. Carbon conversion efficiency improved from85 to 88% and gas yields.

Effect of addition of catalysts.

In order to improve the quality of gas and performance of FBG a naturally occurred catalysts like, Dolomite and olivine were added in different proportions at the ER of 0.3 and 0.35. Addition of dolomite and olivine more than 40 wt.% of sand leads to increase the generation of fine particles which increased the problem of maintenance due to blockage of pipes and stability of operation. Therefore; the addition of both the catalysts limited up to 40% on weight basis. The effect of addition of both the catalysts on energy consumption for bed heating, gas quality, gasifier performance has been observed and discussed in the following sections.

Effect on energy consumption for bed heating.

The effect of addition of dolomite and olivine on charcoal consumption, bed temperature achieved with the addition of charcoal and time taken into consideration to reach the corresponding bed temperature is depicted in Table. It was observed that with the increase in the quantity of dolomite in the bed charcoal consumption was increased while in case of olivine it was decreased. It occurs due to extremely high heat retention property, lower loss ignition and higher MgO/SiO_2ratios of olivine compare with the dolomite. Which reduces the energy required to remove the unwanted CO_2in case of olivine to form the active oxides of Fe and Mg The temperature of bed achieved with the addition of charcoal was in the range of 350–450°C and further increase in the bed temperature up to the gasification temperature was achieved with the combustion of saw dust by supplying it at a lower feed rate. For the bed of sand + olivine smooth and fast increase in bed temperature was observed compare with the bed of sand + dolomite.

Effect on producer gas composition

With the increase in the quantity of dolomite in the bed of sand with an increase in ER (0.3–0.35), H_2content increased from 2.5 to3.6% and 2.4 to 3.4%, CO content increased from 15.2 to 17.3% and14.1 to 16.1%, CO2content increased from 9.3 to 10.5% and 10.9 to12.1%. Similar trends of variation in producer gas composition were obtained with the addition of olivine in which H_2content increased from 2.6 to 3.65% and 2.5 to 3.26%, CO content increased from 15.2to 17% and 14.1 to 15.8%, CO_2content increased from 9.3 to 10.9%and 10.9 to 12.2% at the ER of 0.3 and 0.35, respectively. CH_4contentin both the cases remained constant around 3.2% and 2.8% at the ER of 0.3 and 0.35, respectively.

Effect on gas quality

The effect of addition of dolomite and olivine from 10 to 40 wt.% at ER 0.3 and 0.35 on gas quality. With the increase in the quantity of dolomite or olivine in the bed of sand, the progressive decrease in the tar + SPM content while progressive increase in the HHV was observed. The reduction in the tar + SPM content was due to the fact that both the catalyst would form the active sur-faces which reduced the temperature needed for the cracking of tar. An increase in HHV of producer gas with the addition of both the catalyst is because of the progressive increase in the $H_2$and Content and constant CH4content. This is considered as a major advantage of catalytic cracking compared with other methods as it does not reduce heating value of gas after the removal of tar because it converts tar into gaseous products like H2and CO by cracking. The overall reduction in the tar + SPM con-tent with the addition of dolomite were 45% and 50% found with an increase in ER from 0.3 to 0.35. While in the case of olivine the over-all reduction in the tar + SPM content were 41% and 44% at the ER of0.3 and 0.35 observed. Dolomite compared with the olivine proved to be better for the reduction of tar + SPM content but at higher con-tent of dolomite (above 20 wt.%) more fine particles were generated which increased the maintenance due to blockage of pipes while olivine shown better resistance to attrition. Similar performance of both the catalysts in terms of tar + SPM reduction were reported. With the addition of dolomite HHV of producer gas was increased from 3.6 to4.1 MJ/m3and 3.3 to 3.75 MJ/m3while with the addition of olivine of producer gas was increased from 3.6 to 4 MJ/m3and 3.3 to3.68 MJ/m3at the ER of 0.3 and 0.33.

VI. CONCLUSION

Conclusions This study has shown that bubbling fluidized bed gasification of Saw dust has the potential of becoming an alternate source of energy especially in villages of developing countries as producer gas with LHV ranging from 3.3 to 4.1 MJ/m3was produced. ER of 0.3and 0.35 were found the most suitable ERs for the catalytic gasification. Considering the low temperature operations (690–730◦C) satisfactory reduction in tar and SPM by 45 and 50% with the use of raw dolomite and by 41 and 44% with the use of untreated olivine were obtained at the ER of 0.3 and 0.35, respectively. Composition of the bed having 40% catalyst and 60% sand found to be the most suitable one in both the cases as the further addition of both the catalysts in the bed of sand led towards the operational difficulties and maintenance issues. Thermal energy required for heating the bed was 50% and 66% low in case of sand + olivine mixture compared to sand and sand + dolomite mixture, respectively. Which indicated that rather than using only the bed of sand use of sand and naturally occurring catalyst in right combination as a bed material would provide gas with much better quality at same.

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