

A Review on Co-Gasification of Biomass and Coal

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Abstract- Gasification is an indirect combustion process of converting solid fuels into combustible gas. Various types of gasifiers have been developed based on the requirements such as fuel flexibility, tar percent of out-coming gas, maximum temperature in reactor etc. Biomass gasification is a much understood technology at its present level. Adding the coal to biomass helps in usage of coal in more environmental friendly and clean way. Present work reviews on co-gasification of biomass and coal in fixed and fluidised bed gasifiers in order to study synergy between both biomass and coal. This work also sheds some light on the single particle experimental work conducted on biomass and coal. It has been found that the increase in the coal percent in the fuel blend on weight basis led to the decrease in the synergy of the co-gasification of biomass and coal because of ash fusion problem.

I. INTRODUCTION

A. Gasification

In the general context, gasification is often described as the combustion in sub stoichiometric air-fuel ratio condition. But this definition does not completely describe the process of gasification. Prior to defining what is gasification let's discuss Pyrolysis first. Pyrolysis stands for evolving of volatiles out of the fuel when the fuel is exposed to high temperatures in absence or presence of little amount of oxidizing agent. Now it is defined as the "oxidative pyrolysis coupled with hot char caused reduction reactions". In broader aspect gasification encompasses 4 processes which are drying, pyrolysis, combustion and reduction finally in a typical downdraft gasifier. Drying includes the removal of moisture from fuel and in the pyrolysis volatiles get evolved out from fuel leaving behind the char. Char undergoes combustion in the oxidation process and the volatiles get reduced in reduction process [1].

B. Necessity of Gasification Over Combustion

The question of necessity of the gasification arises often when we can make do with combustion. In the present work which includes the gasification of coal above questions' importance increases since coal serves major fulfilment of energy requirement of world. The product of combustion are always product gases which are used in turn to transfer heat to water to form steam which will run a turbine, generating the electricity. Whereas in case of gasification, the product gases will be producer gas which has multiple applications. The producer gas can be combusted either locally or at a distance like in IC engines, gas turbines or in fuel cell. Moreover the producer gas can be used for the production and synthesis of many chemicals such as methanol and biodiesel which are emerging like new alternative fuels in the field of energy sector. From the conception of the Carnot efficiency for combustion of any fuel, it is evident that the highest temperatures are observed in the combustion of gas

compared to that in the steam even at higher pressures. Thus the efficiency of the gasification process in case of use of solid fuels stand out in the field of combustion science [1].

II. TYPES OF GASIFIER

Many types of gasifiers have been designed based on the type of fuel used, ash percent in the fuel, fuel flexibility, tar percent in the out-coming producer gas etc. each type of gasifiers have been explained from their era of their development.

1. Updraft gasifier

If we go by the name, these gasifiers employ draft of oxidizing agent or air from the bottom to the top of the gasifier. Hence the name "updraft". In the updraft gasifiers the fuel supplied is made to flow from top of the reactor to the bottom where a grate is present over which the burning of the feedstock takes place. The major advantages of this type of gasifier is its simplicity, better carbon conversion and internal heat exchange leading to low gas exit temperatures and high system efficiency, as well as the possibility of operation with various types of feedstock. The major drawback is high tar content in the output gas and the cleaning of output gas. This type of gasifier is used for direct heat application in which tar is simply burnt [2].

2. Downdraft gasifier

Downdraft gasifiers employ flow of fuel from top of reactor whereas the oxidizing agent from the side tuyers in the classical closed top. In the downdraft system of the closed-top type air is drawn from the tuyers arranged around the periphery to enter a zone below the fuel storage section. Sometimes, the storage section is increased in size to store enough fuel for 6 - 10 hours of operation. The air comes via nozzles at reasonably high velocities of 5 - 30 m/s, the high velocity being chosen to enable penetration into the core region in larger size reactors. Imbert class of close-top reactors employ velocities in the range of 20 to 30 m/s. Below the air nozzle, space is provided up to a zone where the gas flow is designed to pass through a constriction passage, called throat. This ensures that the hot gas gets mixed well with the air and flows through the throat region in the porous bed of char [1]. The main advantage of the downdraft gasifiers over the updraft is the low tar content of the producer gas coming out of the reactor which is mainly because of the burning of the higher hydrocarbons of volatiles in the combustion zone where sufficient amount of oxidizing agent will be supplied through side tuyers [1].

3. Crossdraft gasifier

The crossdraft gasifiers are designed in such way that the flow of oxidizing agent and the fuel flow occur in perpendicular direction giving the name "crossdraft". Because of the high temperature existing near the side nozzle in the gasifier from where oxidizing agent enter, generally fuels with high ash fusion temperature are preferred for their usage in the crossdraft gasifiers. When the charcoal is used as fuel for these type of gasifier temperature may go up to 1500° C causing material failure thereby limiting the application of the crossdraft gasifiers to limited extent [3].

4. Entrained flow gasifiers

Entrained flow gasifiers were developed bit late compared to other types of gasifiers. This type of gasifiers belong to second type of gasifiers, when the gasifiers are classified based on the type of bed incorporated in the gasifier. Type of bed in all the 3 gasifiers explained above is fixed bed whereas the entrained flow and fluidised bed gasifiers exhibit the fluidised bed on the reactor. In the entrained flow type gasifiers, both fuel and the oxidizing agents are both fed from the top of reactor, because of which the fuel particles fed get entrained by the oxidizing agent, hence the name "entrained". Since the temperatures encountered are higher compared to other type of gasifiers because of which the coal is used as the fuel in most cases in entrained flow gasifiers. The producer gas is drawn out from the bottom of the reactor. Because of prevailing higher temperatures inside the reactor residence time for the fuel particle is low, leading to very short time taken for the production of the producer gas with the initial time being taken as the time of fuel feeding. Since very short residence time will be available for the fuel particles, amount of oxidizing agent supplied is more for entrained flow gasifiers compared to other type of gasifiers [4].

5. Fluidised bed gasifiers

Fluidised bed gasifiers are second type of the gasifiers having fluidised bed other than the entrained flow gasifiers. Fuel particles are fed from the side of the reactor along with some catalysts whereas the oxidizing agent is blown into reactor from its bottom at sufficiently high velocities so that the fuel particles get suspended in the bed of oxidizing agent. Since the fuel particles are surrounded by the oxidizing agent from all the directions the conversion efficiency of fuel in fluidised bed gasifiers is more compared to other type of gasifiers. Generally small sized particles of fuel are fed to the gasifiers because of 2 difficulties which arise with use of heavy and large particles. One is more conversion time taken by the larger particles to produce gas. Second difficulty is collapsing of the bed due to settling down of larger particles because of their heavy weight [4, 5].

III. LITERATURE REVIEW

In the following section the literature review on co-gasification of biomass and coal is presented. Prior to the review on the work of co-gasification, work done on single particle experiments is also done since the single particle experiment helps in knowing burning characteristics of both fuels that are selected for the co-gasification purpose.

i) Single particle experiments

Single particle experiments are conducted on biomass and coal by combusting them in the oxidizing atmospheres.

Wayne W Simmons conducted experiments on the single particle of wood spheres in order to know the effect of variation of parameters on the burning of particle of varying diameters. An experimental set up used by him included arrangement to vary the percentage of the oxygen in the mixture of oxygen and nitrogen, used as oxidizing agent for combustion of the particle. U-shaped heating element was used for the heating of the particle. And provision was made to remove the products of the combustion of particle by a valve arrangement. From the experiments it was found that the particle burnt in two distinct phases with one followed by the other. In the first phase all volatiles were released and got burnt in the form of flame envelope around the particle termination of which indicated start of the second phase where the left out char got combusted heterogeneously in the presence of oxidizing environment. The burning rate of the particle was found increased with increase in the oxygen in the mixture of oxygen and nitrogen. It was also observed that the burning rate got increased by decrease in the size of the particle and went on decreasing with increase in the moisture percent of the particle [6].

Raza Khatami et al conducted experiment on the single particle combustion of the coal particles of varying ranks. The set up for the experiment include cinematography and the pyrometry in order to capture the process of burning of coal particles. The particles were dropped from the top of vertical drop tube furnace walls of which are maintained at constant temperature. The particles underwent combustion while moving from the point of dropping to bottom of furnace. From the experiments it was observed that the bituminous coal particle burnt with cleat distinct behaviour of burning in two phases with first phase of de-volatization followed by the heterogeneous char combustion phase. The same behaviour could not be found from burning behaviour of the sub-bituminous coal particles since they burnt with no clear distinction of de-volatization and heterogeneous char combustion phase. When observed for the lignite particles there was no difference found in the de-volatization and char combustion phase and breaking of the particle was also observed for the lignite particles during their burning [7].

ii) Co-gasification of biomass and coal

Co-gasification of biomass and coal experiments were conducted in different reactor configurations and with different fuels having varying ash percent and at different operating conditions. Some of the works are reviewed as follows

Monikankana sharma et al conducted experiments on the co-gasification of biomass and coal using fixed bed downdraft gasifier developed at IISc. Single particle experiments were conducted first in order to determine the size of particles to be fed to gasifier, after which gasifier was run with fuel blend of biomass and coal. Biomass used was casuarina wood and coal used were of two types of Indian coals, one with 12% ash and other with 21% ash. It was observed that the synergy between biomass and coal decreased with increase in the coal percent in the fuel blend on weight basis. Increasing coal percent also resulted in higher ash fusion problem because of high temperatures. Addition of steam found useful in lowering the ash fusion problem by reduction in the temperature of the bed [8].

Kumabe et al did co-gasification of coal and biomass in the fixed bed downdraft reactor which is one of many experiments of co-gasification performed using fixed bed configuration other than the work by Monikankana sharma et al. Biomass used was Japanese cedar and coal used was Mulia coal (1.1% ash). The feedstock size of both fuels used was in the range of 0.5- 1 mm (equivalent diameter). The furnace temperature was maintained at 900° C with help of an electrical furnace. Provision was made to pass both air and steam through both top as and side nozzles. Biomass and coal were fed using the screw feeder from top. A perforated disk was used for holding the alumina balls which were used as the catalyst for the gasification process. An arrangement was also made to measure the tar percent in the producer gas by the anisole filled bottle placed in the path of the producer gas. From the results of experiments it was found that with increase in the biomass percentage in the fuel blend on weight basis, H₂ percentage in the gas composition decreased whereas the CO₂ percentage increased. The CO percentage in the gas composition found unaffected by the biomass percentage on the fuel blend of biomass and coal. No synergy was observed between coal and biomass when compared from the basis of carbon conversion from fuel fed into the producer gas and the ash extracted [9].

Juan J Hernandez conducted experiments on the co-gasification of biomass and coal in an entrained flow gasifier. The biomass used was the grape marc left out after the dealcoholisation. The coal-coke mixture was used to blend with the grape marc obtained from the wine industry. Coke is residual product from the petroleum industry. Both fuel and the oxidizing agent were fed from the top of the reactor. Steam and air were used as two oxidizing agents and gas chromatograph was used for the gas composition measurement of the producer gas. Part of the gas was sent to the gas composition measurement and some other part was used for the tar percent measurement in the producer gas and little part is sent for the synthesis of the chemicals and rest was sent to burner. Furnace was used to maintain 3 different temperatures at different zones in the reactor ranging from 750° C to 1050° C. From the results of the experiments it was found that the irrespective of the temperature the cold gas efficiency and gas quality increased with increase in the biomass percentage in the fuel blend. Unlike the other cases synergy was found in this experiments in temperature range of 750° C to 850° C [10].

IV. CONCLUSION

From this work it has been concluded that the synergy between both biomass and coal decreased with increase in the coal percent in the fuel blend on weight basis for the experiments conducted in fixed bed downdraft gasifiers and steam was found helpful in lowering the ash fusion problem and increasing the gas quality. For the fluidised bed gasifiers some hints of synergy were observed at lower temperatures comparatively.

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