A Comparative analysis of combustion of Pet coke and Co-firing of pet coke with rice husk in fluidized bed combustion by SEM analysis

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Abstract

Energy is vital for the social and economic development of any nation. The demand of energy is increasing rapidly world widely with development of civilization and growing industrialization. The requirement of energy demand is met by fossil fuels or conventional energy sources. But due to the depletion of fossil fuels there is an urgent need to effectively tap the non conventional and renewable energy sources. The investigations take place in a 32.5TPH boiler of Vishal Paper Mill (VPM), Khusropur. Vishal paper mill Owner took step to use non conventional source of energy, when they set up a 32.5TPH boiler in village Khusropur (Dist. Patiala, Punjab). The whole unit of boiler setup was designed and manufactured by Cheema Boilers Ltd.(CBL) India. This is basically a mini thermal plant in which the heat energy is released on the combustion of biomass and pet coke. The plant works on the 100 % biomass, 100% pet coke and co-firing of rice husk with coal based upon the load and availability of the fuel. The agglomeration samples were also collected from the plant. The agglomeration is the most commonly occurred problem in the fluidized bed combustion which is frustrating for the operator and sometimes the operation has to be stopped leading to the production and money loss. During the time of study plant uses 100% pet coke and 80% rice husk + 20% pet coke as the fuel. The main purpose of this study is to determine the causes of the agglomeration while using the pet coke only and for co-firing for this SEM analysis is done on the agglomerate collected from the plant

Key Word: Fluidized bed combustion, Scanning electron microscope, Pet coke, Rice husk

1. Introduction

Fluidized bed combustors are widely used in the power plants for the production of power. Fluidized beds are also going to be widely used in the next generation power plants in aiding conversion of coal to clean gas. However, in spite of their ubiquitous application, understanding of the complex multi-phase flows involved is still limited. A fluidized bed combustor consists of a collection of inert particles suspended in an upward flowing gas stream at such a velocity that the particles are not carried out of the vessel but continue to circulate vigorously within the vessel. Cavities usually called 'bubbles' move through the suspended mass, which help the vigorous circulation of the bed material. Since the bed offers resistance to flow, the drag forces, as given by pressure drop across the bed, are sufficient to support the weight of the bed. Fluidized bed combustors having advantage of smooth liquid like continuous flow of particles which allow controlled operation with ease of handling and makes it suitable for large-scale operations. It allows rapid mixing of solids that leads to nearly isothermal conditions throughout the bed. As a result of which the operation can be controlled easily and reliably. Heat and mass transfer rates between gas and particles are high when compared with other modes of contacting. Since the bed temperature is kept normally below 1000^{O}C, little atmospheric nitrogen is converted to NO_X. Any type of fuel can be used in the system.

1.2 Mechanism of Fluidized Bed Combustion Systems

When an evenly distributed air or gas is passed upward through a finely divided bed of solid particles such as sand supported on a fine mesh, the particles remain undisturbed at low velocities. As the air velocity is gradually increased, a stage is reached when the individual particles are suspended in the air stream and the bed is called "fluidized". With further increase in air velocity, there is bubble formation, vigorous turbulence, rapid mixing and formation of dense defined bed surface. The bed of solid particles exhibits the properties of a boiling liquid and assumes the appearance of a fluid "bubbling fluidized bed". At higher velocities, bubbles disappear, and particles are blown out of the bed. Therefore, some amounts of particles have to be re-circulated to maintain a stable system and is called as "circulating fluidized bed". This principle of fluidization is illustrated in Figure1.

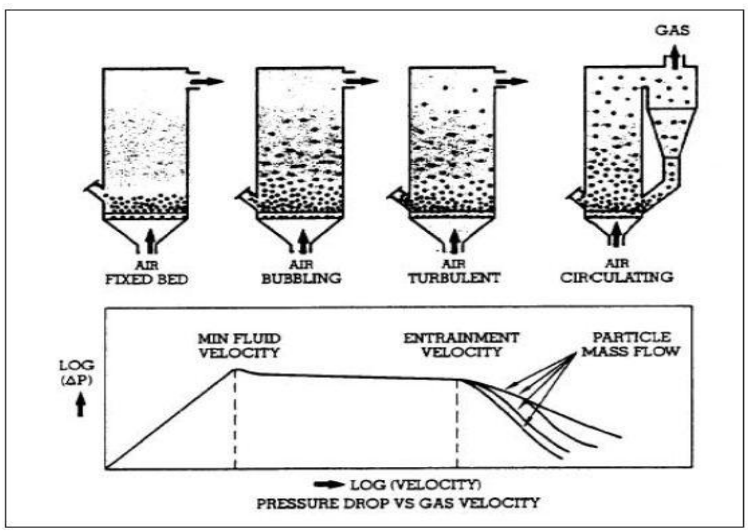

Figure 1 Principle of Fluidization

Any combustion process requires three "T"s - that is Time, Temperature and Turbulence. In fluidized bed combustor, turbulence is promoted by fluidization. Improved mixing generates evenly distributed heat at lower temperature. Residence time is many times higher than conventional grate firing. Thus a fluidized bed combustor system releases heat more efficiently at lower temperatures. Since limestone can also be used as particle bed (in case the fuel with sulphur content is used), control of SO_x and NO_x emissions in the combustion chamber is achieved without any additional control equipment. This is one of the major advantages over conventional boilers.

2. Literature Reviewed

Natrajn et al. [1998] studied the agglomeration tendencies of some common agricultural residue in fluidized bed. The agricultural residue chosen for the study were rice husk, bagasse, cane trash and olive flesh. The results showed that the initial agglomeration temperature was less than the initial deformation temperature predicted by the ASTM standard ash fusion test for all fuels considered. The initial agglomeration temperature of rice husk and bagasse were more than 1000°C. The agglomeration of cane trash and olive flesh was encountered at relatively low temperature and their initial agglomeration temperature in gasification was lower than those in combustion with both bed materials. The use of lime as bed material instead of quartz improved the agglomeration temperature of cane trash and olive flesh in combustion and decreased the same in gasification. The results indicated that rice husk and bagasse could be used in the fluidized bed for energy generation since their agglomeration temperatures are sufficient high.

Skrifvas et al. [1999] tested the agglomeration behavior of different biomass ashes in a pilot scale fluidized bed combustor systematically with programmed temperature change without combustion. Further it was examined that the defluidization temperature, at which the sand bed containing biomass was de-fluidized was close to the initial sintering temperature of the ash determined by compression strength method.

Ryabov et al [2003] reported that traditional way to reduce the negative effects of bed agglomeration was lied in increasing the bed drain with the addition of fresh inert material. Further it was elaborated that chemical and physical characteristics of bed materials must be interpreted to a suitable form for the boiler operation.

Weiganag et al. [2003] described that agglomeration and defluidization phenomenon in fluidization bed combustors based on wheat straw. They found that defluidization was caused by the high content of potassium in straw ash. During combustion the potassium in straw was transformed from organic and inorganic forms to various salts and amorphous of K_2O-SiO_2. The compounds were clearly identified as the coating layer on the sand surface, which caused the formation of agglomerates and eventually defluidization.

Elisabet at al. [2005] studied the mechanisms of bed agglomeration during fluidized-bed combustion of biomass fuels. The low-melting calcium-based silicates including minor amounts of for example potassium were formed with subsequent viscous-flow sintering and agglomeration. For high alkali containing biomass fuels, direct attack of the quartz bed particle by potassium compounds in a gas or aerosol phase formed a layer of low-melting potassium silicate. Thus, formation and subsequent viscous-flow sintering and agglomeration seemed to be the dominating agglomeration mechanism for these fuels.

Korbee et al. [2006] reported an early agglomeration recognition system (EARS) for small scale bubbling-fluidized bed combustors. The small scale bubbling-fluidized-bed gasification and combustion tests with various fuels have shown that agglomeration can be recognized 30-60 min earlier with EARS than with conventional methods based on change in pressure drop or temperature difference. EARS may help plant operators in preventing agglomeration-induced plant shut down and minimizing bed material makeup and residue production.

Singh et al [2008] describes production of sulphur and nitrogen dioxide was reduced by using the low bed temperature up to 800 C. A solid population model was used to calculate the bed carbon load and carbon utilization efficiency. It was found that with the increase in the depth of bed the concentration of oxygen decreases and percentage of carbon dioxide increases. The problem found was the defluidization of bed exists which causes to stop the operation of the bed due to the agglomeration and the agglomeration was due to potassium, magnesium and sodium present in the rice husk.

Skrifvas*et al,.*andNordin*et al,.*[2009] tested the agglomeration behavior of different biomass ashes in a pilot scale fluidized bed combustor systematically with programmed temperature change without combustion. Further it was examined that the defluidization temperature, at which the sand bed containing biomass was de-fluidized was close to the initial sintering temperature of the ash determined by compression strength method.

3. Description of 32.5TPH Boiler of Vishal Paper Mill(VPM), Khusropur

Vishal paper mill Owner took step to use non conventional source of energy, when they set up a 32.5TPH boiler in village Khusropur (Dist. Patiala, Punjab). The whole unit of boiler setup was designed and manufactured by Cheema Boilers Ltd. (CBL) India. This is basically a mini thermal plant in which the heat energy is released on the combustion of biomass and pet coke instead of whole use of coal. The water is converted into superheated steam from this heat energy. The superheated steam is used to run steam turbine, which is coupled with generator to produce electricity. Storage tank is made to fulfill the requirement of water. The generation voltage of power is 11kV, which is stepped down and linked with the paper mill industry. Plant is semi-automatic which uses conveyor for feeding fuel. In the control room, all the main controls of plant and other parameters can be handled from a single computer. Rice husk and pet coke are fed to the conveyor belt using rollers. Fuel through conveyor belt is passed to boiler for incineration. Any type of biomass (rice /wheat husk, cotton waste, bagasse, tree chips, rice straw, saw dust, and cow dung cakes etc. can be used. At the time of study fuel used is rice husk and pet coke. A consortium of type is shown in Figure 2, in order to ensure adequate raw material for the plant has been formed.

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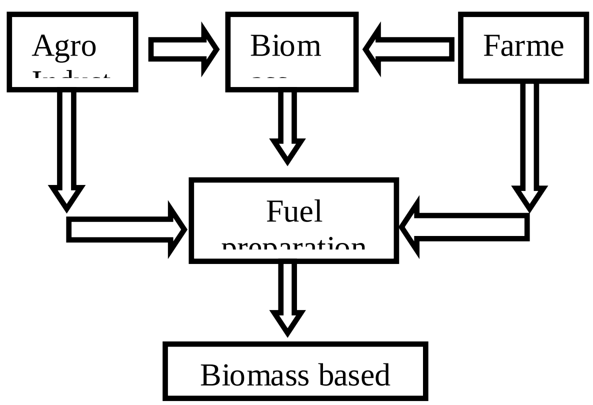

Figure 2 Consortium for collection of Biomass

4. Result & Analysis of SEM

The Scanning electron Microscope (SEM) test has been done on the agglomerates sample collected from the 32.5TPH boiler of Vishal Paper Mill (VPM), Khusropur with 100% pet coke and 80% rice husk + 20% pet coke. The SEM test has been done on the SAI Lab at Thapar University Patiala.

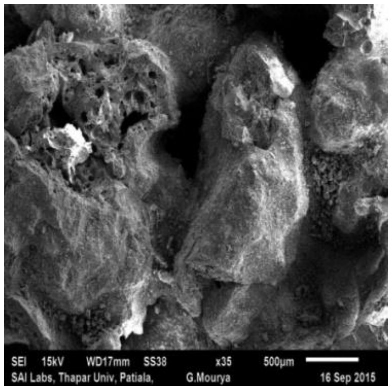

Figure 3 SEM results of co-firing

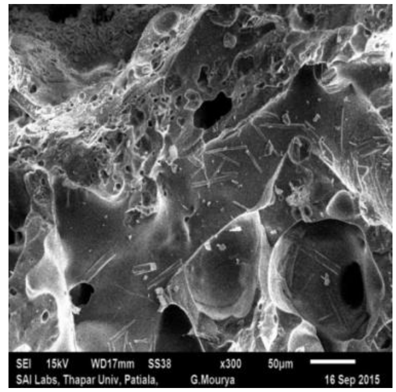

Figure 4 SEM results of co-firing

Figure 3 and figure 4 shows the SEM results of the agglomerate collected from the bottom of the Furnace from the 32.5TPH boiler of Vishal Paper Mill (VPM), Khusropur with co-firing of 80% rice husk + 20% pet coke. Figure 5 and figure 6 shows the SEM results of the agglomerate collected from the bottom of the Furnace from the 32.5TPH boiler of Vishal Paper Mill (VPM), Khusropur with firing of 100% pet coke.

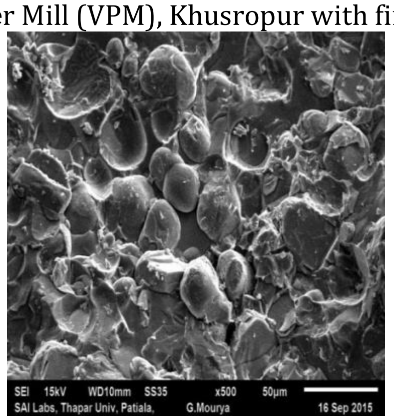

Figure 5 SEM results of coal

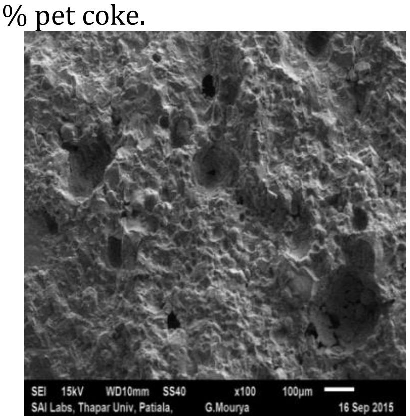

Figure 6 SEM results of coal

As shown in the above test result it is clear that while using the co-firing of the rice husk with the coal bonding between the particles is less strong and one particle is merged into the other particle as shown in figure 3 & 4 and while using only pet coke only the bonding between the particle is large as shown in figure 5 & 6. So where we are using co-firing bonding between the particle is less strong agglomerates can be easily broken hand on the other hand a large quantity of force is needed to break the agglomerate by using pet coal only.

5. Conclusion

1. The Agglomerate formed while using pet coke is hard as compared to the co-firing.
2. The combustion efficiency is reduced using pet coke only.
3. The carbon utilization efficiency of the plant decreases while using pet coke only as compare to the co-firing

References

1. Chyang C.S., Duan F., Lin S.M., Tso J. (2012) A study on fluidized bed combustion characteristics of corncob in three different combustion modes. Bio resource

Technology, vol. 116, pp. 184—189.

2. EL-HalwagiMabmoud M. and EL-Rifai Mahmoud A. (1988) Mathematical modeling of catalytic fluidized bed reactors-I. The multistage three-phase model. Chemical Engineering Science, vol. 43, No. 9, pp. 2477-2486.
3. EL-HalwagiMabmoud M. and EL-Rifai Mahmoud A. (1988) Mathematical modeling of catalytic fluidized bed reactors-I. The multistage three-phase model. Chemical Engineering Science, vol. 43, No. 9, pp. 2477-2486.
4. Kataja T. and Majanne Y. (2007) Dynamic model of bubbling fluidized bed boiler. pp.140-148.
5. Natrajan E, Nordin A, Rao A.N. (1998) Overview of combustion and gasification of rice husk in fluidized bed reactors. Biomass Bio energy, vol.14, pp. 533—46.
6. Singh R.I, Mohapatra S. K., Gangacharyulu D.(2008) Studies in an atmospheric bubbling fluidized bed combustor of 10 MW power plant based on rice husk. Energy Conversation Management, vol. 49, pp.3086-3103.
7. Weber S., Briens C., Berruti F., Chan E., Gray M. (2006) Agglomerate Stability in fluidized beds of glass beads and silica sand. Powder Technology, vol. 165, pp. 115-127.