Effect of particle size on optimum air levels required for packed bed combustion of biomass

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ABSTRACT

A relation between the particle size and excess air flow rate for packed bed combustion of biomass has been the objective of this research project. Particles of square cubes of different dimensions and different air flow rates have been used in a 40cm×40cm×80cm combustion chamber to determine the above mentioned relation. The combustion rate has been determined by measuring the rate of combustion of the packed bed. A probe was utilized to measure the flue gas temperature at the exit. A mathematical model is developed relating these parameters.

Keywords: biomass; particle size; excess air

INTRODUCTION

The most conventional method converting the chemical energy of biomass into thermal energy is packed bed combustion. Although there are two main types of packed bed combustion, namely; grate furnaces and underfeed stokers, in our study we have used a grate furnace, since it is most suitable for small scale batch combustion. Here, fairly large particles of solid remaining at rest are combusted and air is supplied from beneath. Packed bed combustion is simple to operate and minimum fuel preparation is required.

METHODOLOGY

- A proximate analysis was done prior to combustion to determine the properties of the wood that is being used. This allowed the determination of moisture content, volatile matter content, ash content, and fixed-carbon content of wood.
- The combustion of the wood particles was done in batches and required readings were taken at regular time intervals.
- The parameters measured were rate of combustion, temperature of the flue gas and the composition of flue gas for combustion of a particular wood particle at a particular air flow rate.
- The measuring of the parameters was done as follows.

  - Rate of combustion – The furnace was suspended from a digital weight scale. With 4 rings attached to each side plate of the furnace was hooked and chains were used to suspend the furnace from the digital weight scale. A pulley was attached to the weight scale to hoist and descend the furnace.

The weight of the furnace was measured at regular time intervals and the rate of

combustion was determined by the readings.

- Temperature of the flue gas – A RTD was used to measure the temperature of the walls of the furnace at pre-assigned positions and the exit temperature of the flue gas from the top of the furnace.

1.1 Particle sizes and air flow rates used

Particle Size
2cm
4cm
5cm

Air Flow Rate (×10^{-4})
175 m^3s^{-1}
102 m^3s^{-1}
74 m^3s^{-1}
32 m^3s^{-1}

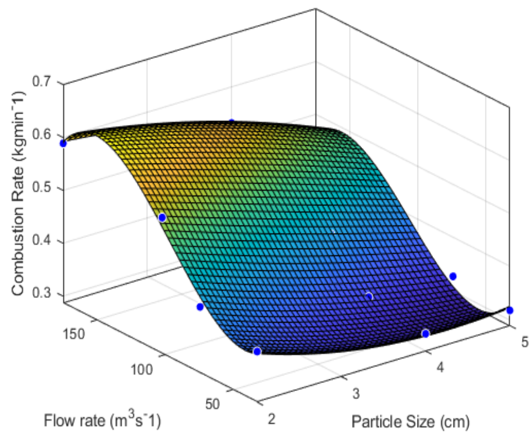
RESULTS AND DISCUSSION

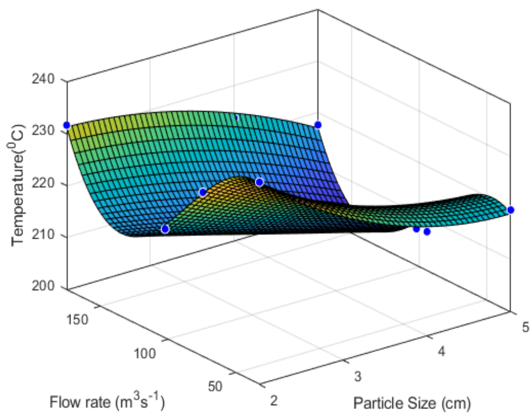
By conducting the experiments for above combinations of particle sizes and air flow rates following steady state combustion rates and flue gas exit temperatures were obtained. Surface plots generated using MATLAB, for these parameters are as below.

3.1 Combustion rate (kg/min) and flue gas exit temperature (°C) variationagainst flow rate and particle size

(×10^{-4})	2cm	4cm	5cm
175 m^3s^{-1}	0.589	0.531	0.466
102 m^3s^{-1}	0.545	0.417	0.368
74 m^3s^{-1}	0.413	0.335	0.326
32 m^3s^{-1}	0.384	0.321	0.317

(×10^{-4})	2cm	4cm	5cm
175 m^3s^{-1}	231.7	223.7	217.7
102 m^3s^{-1}	221	213.8	207
74 m^3s^{-1}	231.7	218.7	215.8
32 m^3s^{-1}	239	220.1	219.6





Here, steady state combustion rates were determined by considering the trend line of the linear sections of each weight loss curve obtained by experiment and flue gas temperature is the average temperature observed during 20-30 minutes upon combustion initiation in each run.

These surface plots indicate a qualitative relationship for these parameters against the manipulated variables.

CONCLUSION

Steady state combustion rates achieved for each particle size increase with the increase of air flow rates but the rate of this combustion rate increment, shows an increase at first and then decreases beyond a particular optimum air flow rate. Flue gas exit temperatures indicates a trend of increasing values followed by a decrease with increase of air flow rates for each particle size. Maximum temperature of flue gas observed for each particle size is experienced at an air flow rate lesser than the level at which greatest combustion rate occurs.

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