Determination of Free Falling Velocity of Wet Bagasse

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***Abstract*— The focus of this work is to determine the free falling velocity of bagasse particles. The reactor was designed and constructed for the drying of sugarcane waste. Design of experiments was performed to evaluate the novel free falling reactor by varying three operating conditions: air temperature, biomass particle size, and biomass feed rate. Particle sizes of 1 cm, 2 cm, 3 cm was to be tested with carrier atmospheric air flow rates of 16.4 m/s. optimal free fall heights were identified for determination of drying hopper height.**

Keywords—Free Falling; Bagasse Moisture; Fluidized Bed Reactor; Bagasse Drying; Pneumatic Dryer

I. INTRODUCTION

The goal of this work is to develop a new biomass fast pyrolysis reactor that improves upon inefficiencies in traditional reactors. Many fast pyrolysis reactors exist but the most suitable reactor has not been identified [1] Reactors like the bubbling fluid bed and circulating fluid bed require large amounts of carrier gas to mix a heat carrier with biomass while the spinning disk, rotating cone and auger reactors have many hot moving parts. These factors may increase the complexity of the reactor and make them expensive to operate or repair. More work is needed to investigate novel reactor types that overcome these disadvantages without compromising high bio-oil yield. A free-fall hopper reactor was selected for this work because of its simple design and lack of drying space. The reactor was optimized and evaluated for the drying hopper height design of experiments. Operating conditions including the air temperature, biomass particle size, and biomass feed rate were varied. The Atlas covers 642 sugar mills in India with State-wise /District-wise maps and salient information of every sugar mills in India [18]

1.1 Reactor Technology

The reactor is the central component when considering an entire fast pyrolysis system. Since it is the key component many reactors have been developed in order to improve upon old methods and create proprietary technology. The oldest and most well-understood is the bubbling fluidized bed or simply the fluid bed reactor as shown in Fig 1.1 [2].

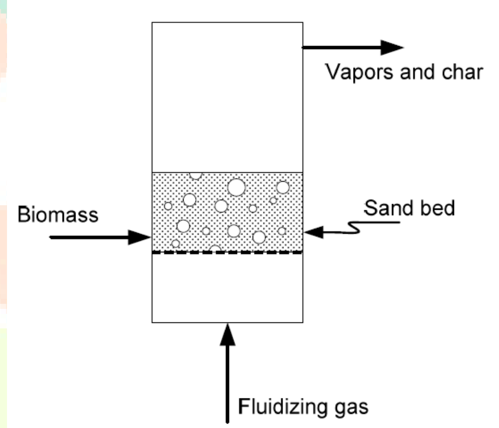


Fig 1.1: Fludized Bed Reactor

1.2 Free-fall Reactors

Free-fall reactors are also referred to as drop-tube reactors. Free-fall reactors have been used for many applications including gasification of coal [3-4], the pyrolysis of polystyrene and polyethylene [5, 6], kinetic studies [7, 8] as well as various biomass pyrolysis studies [9-12].

TABLE 1.1: COMPARISON TABLE FOR VARIOUS PYROLYSIS AND DRYING PROCESS OF BIOMASS IN FREE FALL REACTORS [15]

S. No	Author	Process	Reactor Inner Diameter (m)	Reactor Length (m)	Heating Arrangement	Feeding Rate (g/hr)	Particle Size (mm)	Temp. (°C)	Yield Wt %
1.	Zhang et al	Pyrolysis of Coal and Biomass	0.02	1.8	Electrical Heater	2100	0.3-0.45	500-700	73 wt %
2.	Li et al	Hydropyrolysis of coal	0.01	0.3,0.7,1	Heater	6-9	-	400	15 wt %
3.	Zanzi et al	Pyrolysis of biomass	0.04	2.9	Heater	1000	0.5-1	750-1100	5 wt % bio-oil yield
4.	Yu et al	Pyrolysis of birch wood			Heater	1000	0.5-0.75	700	8 wt % bio-oil yield
5.	Onay and Kocker	Production of bio-oil from rapeseed	0.012	0.7	Electrical Heater	120	0.224-1.22	400-700	68-75 wt % bio-oil yield
6.	Yorgun et al	Pyrolysis of sun flower oil cake	0.035	0.6	Electrical Heater	120	0.224-0.850	450-700	45 wt % Liquid yield
7.	Matsuoka et al	pyrolysis at the early stages in gasification using a drop tube reactor	0.0076	1.83	Furnace Heater	6	0.075-0.15	600-750	5 wt % Liquid yield

A few studies performed the fast pyrolysis of biomass in a free-fall reactor and report notable bio-oil yields though bio-oil production was not necessarily the purpose of study [13, 14]. Most of the free-fall, drop-tube or entrained flow reactors reported are constructed for lab scale experimentation as shown table 1.1. Char, tar, gas and liquid are yielded product from pyrolysis of biomass process.

Though free-fall type reactors had been used for many applications very few had been used for the pyrolysis of biomass to produce bio-oil. Two studies that had reported significant bio-oil yields examined the effects of temperature, particle size and carrier gas flow rate [16, 17]. Both performed parametric studies using lab scale reactors with small biomass feed rates (2 – 6 g/min) to determine conditions favouring maximum product yield; not necessarily bio-oil. There had been little research examining the effect of biomass feed rate on bio-oil yields and no research examining interaction effects between parameters or optimizing bio-oil yields. The development of a 1 kg/hr (16 g/min) free-fall reactor for the production of bio-oil provides an opportunity to examine key areas of research that have not been studied. A typical schematic diagram of free-fall reactor shown in Fig 1.2

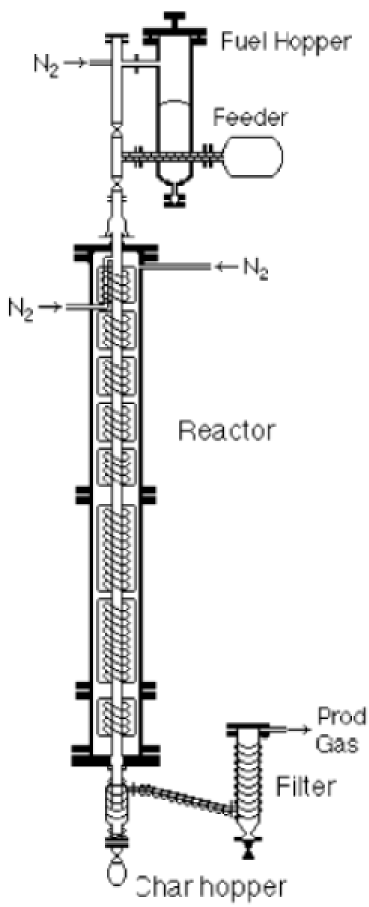


Fig 1.2: Schematic diagram of free-fall reactor [15]

II. Materials and Methods

2.1 Reactor Design

Various configurations and sized free-fall reactors have been used in a wide range of applications. The free-fall reactor has no moving parts and is simple to construct, operate and maintain. A number of calculations and assumptions were made during the design phase of this project. Two basic principles were combined in the design of the free-fall reactor. The first principle dealt with the particle size and the second involved the particle's free-fall velocity. After integrating both of these concepts, one can determine both the required wall height of the reactor. The required apparatus shown in Fig 2.1.

Fig 2.1: Apparatus required for Free-fall Experiment

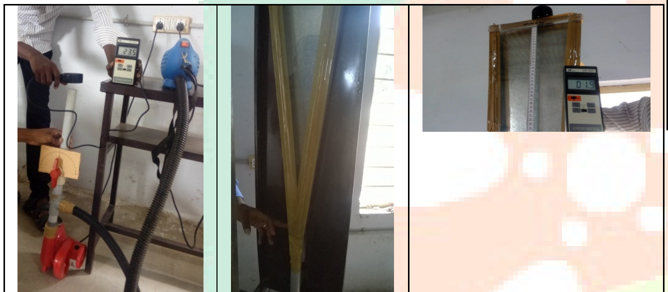
1. Anemometer is used to measure the air velocity
2. Ball valve is used to control incoming air velocity
3. Infra red thermometer is used in this experiment for measuring air, bagasse, and duct temperature
4. Reactor duct – one side is visible for measuring the free fall velocity

Fig 2.2: different sizes of wet bagasse particles

Conical duct was designed based on incoming air velocity and 7° Angle (Industrial standard fluid flow duct angle)[19]. Conical duct was made by using GI Sheet and the front of the duct is replaced by glass for the purpose of clear visible .
In this experiment 3 various sizes of bagasse particles are used to conduct the freefalling velocity test. The sizes of bagasse particles are10 mm, 20 mm, 30 mm as shown in Fig 2.2.The duct inlet air velocity is 16.4 m/s, and the outlet air velocity is 1.3 m/s.

2.2 Particle Free-fall Velocity

Knowing the restrictions on particle size set by random series. To be conservative, all effects due to particle heating, such as changing density and loss of mass were ignored. The forces on a particle in free-fall height and free fall velocity should be find out from Table 3.1 and Experimental setup shown in Fig 2.3.



1.Incoming atmospheric air flow rate measured	2.Duct fitted incoming pipe	3.Air flow rate measured at the end of duct opening

Fig 2.3: Experimental setup

These three different sizes of bagasse particles colored and fall in the top of the duct. The 10 mm, 20 mm, 30 mm bagasse particles fall in three different heights 250 mm, 350 mm, and 650 mm respectively. The height is measured by using measuring tape as shown in Fig 3.1.

III. Results and Discussion

TABLE 3.1: FREE FALL AIR VELOCITY AT DIFFERENT HEIGHT FROM TOP OF CONICAL DUCT

HEIGHT FROM TOP (meters)	Air Velocity (m/s)
0.0	1.3
0.1	2.6
0.2	3.8
0.3	5.1
0.4	6.3
0.5	7.6
0.6	8.9
0.7	10.1
0.8	11.4
0.9	12.6
1.0	13.9
1.1	15.1
1.2	16.4

The free falling velocity of 10 mm, 20 mm, 30 mm sizes of bagasse particles are 4.0729 m/s, 5.708 m/s, 9.482 m/s respectively.

Fig 3.1: Result of different free falling height

IV. Conclusion

A few suggestions come to mind for the continued use of this experiment. Determination for the free-falling air velocity of wet bagasse, This Experiment will be used in all the world sugar industries various bagasse feeding process, various pyrolysis process and drying process of biomass.

REFERENCES

[1] Bridgwater, A.V. and G.V.C. Peacocke, 'Fast pyrolysis processes for biomass. Renewable and Sustainable Energy Reviews', 2000. 4: p. 1-73.

[2] Bridgwater, A.V., 'The production of biofuels and renewable chemicals by fast pyrolysis of biomass'. International Journal of Global Energy Issues, 2007. 27: p. 160-203.

[3] Lee, J.G., et al., 'Characteristics of entrained flow coal gasification in a drop tube reactor Fuel', 1996. 75: p. 1035-1042.

[4] Xu, W.C., et al., 'High pressure hydropyrolysis of coals by using a continuous free-fall reactor Fuel', 2003. 82: p. 677-685.

[5] Karaduman, A., et al., 'Flash pyrolysis of polystyrene wastes in a free-fall reactor under vacuum'. Journal of Analytical and Applied Pyrolysis, 2001. 60: p. 179-186.

[6] Mastral, J.F., C. Berrueco, and J. Ceamanos, 'Pyrolysis of High-Density Polyethylene in Free-Fall Reactors in Series'. Energy and Fuels, 2006. 20: p. 1365-1371.

[7] Brown, A.L., et al., 'Design and Characterization of an Entrained Flow Reactor for the Study of Biomass Pyrolysis Chemistry at High Heating Rates'. Energy and Fuels, 2001.15: p. 1276-1285.

[8] Lehto, J., 'Determination of kinetic parameters for Finnish milled peat using drop tube reactor and optical measurement techniques'. Fuel, 2007. 86: p. 1656-1663.

[9] Yang, H., et al., 'Pyrolysis of palm oil wastes for enhanced production of hydrogen rich gases'. Fuel Processing Technology, 2006. 87: p. 935-942.

[10] Zanzi, R., K. Sjöström, and E. Björnbom, 'Rapid high-temperature pyrolysis of biomass in a free-fall reactor'. Fuel, 1996. 75: p. 545-550.

[11] Zhang, L., et al., 'Co-pyrolysis of biomass and coal in a free fall reactor'. Fuel, 2007. 86: p. 353-359.

[12] Wei, L., et al., 'Characteristics of fast pyrolysis of biomass in a free fall reactor'. Fuel Processing Technology, 2006. 87: p. 863-871.

[13] Onay, O. and O.M. Koçkar, 'Pyrolysis of rapeseed in a free fall reactor for production of bio-oil. Fue'l, 2006. 85: p. 1921-1928.

[14] Li, S., et al., 'Fast pyrolysis of biomass in free-fall reactor for hydrogen-rich gas'. Fuel Processing Technology, 2004. 85: p. 1201-1211.

[15] Ellens, Cody James, 'Design, optimization and evaluation of a free-fall biomass fast pyrolysis reactor and its products'. Graduate Theses and Dissertations. Paper 11096, 2009.

[16] Onay, O. and O.M. Koçkar, 'Pyrolysis of rapeseed in a free fall reactor for production of bio-oil'. Fuel, 2006. 85: p. 1921-1928.

[17] Li, S., et al., 'Fast pyrolysis of biomass in free-fall reactor for hydrogen-rich gas. Fuel Processing Technology', 2004. 85: p. 1201-1211.

[18] http://www.indiansugar.com/SugarMap.aspx

[19] Dr R Vasudevan CEO of Uttam Sugar Mills Limited, Retd. School of Energy Director, Retd. BHEL GM