VOL. 10, NO 21, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

EFFECT OF THE WATER SPRAY STRESS ON SWIRLING FLUIDIZED BED HEIGHT

Muhammad Yasin Naz[1], Shaharin Anwar Sulaiman[2], Zakaria Man[3] and Bambang Ariwahjoedi[1]
[1]Department of Fundamental and Applied Sciences, Universiti Teknologi Petronas, Bandar Seri Iskandar, Perak, Malaysia
[2]Department of Mechanical Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar, Perak, Malaysia
[3]Department of Chemical Engineering, Universiti Teknologi Petronas, Bandar Seri Iskandar, Perak, Malaysia
E-Mail: yasin603@yahoo.com

ABSTRACT

This study was designed to investigate the effect of spray stress and pressure drop on the height of a swirling fluidized bed of plastic beads. The motivation for conducting this work was primarily an interest in elaborating the fluidized particles response to the water sprayed from top of the bed. It is revealed that the bed height is greatly influenced by both parameters: the pressure drop and spray stress regardless of the bed weight. The air pressure above the bed abruptly decreased with the spray stress whereas an increasing trend in pressure was depicted just below the bed. The increased pressure difference across the bed suddenly lifted the plastic beads from packed to minimal fluidization, then to slug-wavy followed by swirling and a vigorously bubbling bed with lower layer swirling. Overall the height of the bed exposed to the top spray was higher than that without the spray stress. The height of the settled bed of 200 g beads was calculated as 140 mm, which increased to 200 mm with pressure drop of 150 mmH_2O.

Keywords: water spray stress, fluidized bed, air pressure.

INTRODUCTION

Fluidized bed reactors are broadly used worldwide in petroleum and petrochemical industries [1]. Many industrially produced polymers are made using fluidized bed technology, such as rubber, vinyl chloride, polyethylene, styrene, and polypropylene. Fluidized bed reactors are also used in many utilities for coal gasification, oil decontamination of sand, radioactive waste solidification, acetone recovery, nuclear power plants, biomass gasification, particles coating, as well as water and waste treatments [1], [2]. Fluidized bed reactors are ideal for industrial processes such as freezing, drying, heating, cooling, coating, mixing, scrubbing, agglomeration and granulation [3].

Fluidized bed promotes uniform particle mixing, limit pressure drop as well as high mass and heat transfer rates. Fluidized beds are also useful to transport large quantities of solids [4]. However, fluidized bed reactors have their own drawbacks such as non-uniform flow patterns and agglomeration. Effective surface area is reduced by the clustering of fluidized bed particles during agglomeration. In addition, the transition from fixed to fluidized bed is not uniform mainly because of irregularities in the packing over a range of velocities, fixed and fluidized bed regions may co-exist [4], [5].

The spray coating/washing in a fluidized bed system produces an optimal surface coating through an even application of film material. Particles of different shapes and sizes are moved around in the fluidized bed and simultaneously the nozzle placed above dissolves coating material onto the particles in the form of small droplets. The coating can act as a protective layer to increase shelf life or storage stability. Besides that, coating can also be used to hide odour or taste or to release specific active substances. Spray coating is available in both batch and continuous process. Spray coating can be done with top spray, bottom spray or tangential spray [6, 7].

Spray washing or pressure washing is a process utilizing high-pressure mechanical sprayer to remove loose paint, mould, grime, dust, mud and dirt from surfaces and objects. There are dozens of operations in every food processing plants which utilizes the spray technology. Spray washing is also widely used in food industry to remove bacteria from food [5]. Pao *et al.* [7] in their study conducted spray washing on tomatoes with chlorine dioxide to minimize Salmonella on inoculated fruit surfaces and cross-contamination from revolving brushes. In fluidized bed spray washing, the nozzle flow rate should be well optimized to minimize the dry and wet quenching, elutriation of the particles from the bed and process cost. To the author's knowledge, the past literature is lacking in good reports on the systematic study of the effect of spray stress on the fluidized bed parameters in spray washing applications. In this study, a top spray fluidized bed column was designed to investigate the effect of spray stress and pressure drop on the height of the swirling bed of plastic beads.

MATERIALS AND METHODS

Schematic of the laboratory built fluidized bed spraying system is shown in Figure. 1. The top spray fluidized bed column was made up of a plastic cylinder tube of 50 cm length and 19 cm diameter. Plastic beads of

VOL. 10, NO 21, NOVEMBER, 2015 ISSN 1819-6608
ARPN Journal of Engineering and Applied Sciences

www.arpnjournals.com

average diameter of 2 mm weighing 0.05 g each were used as the bed material.

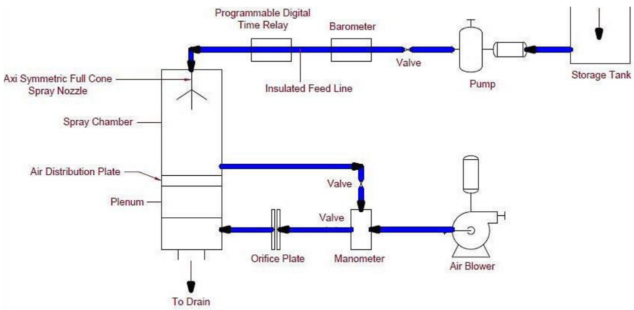


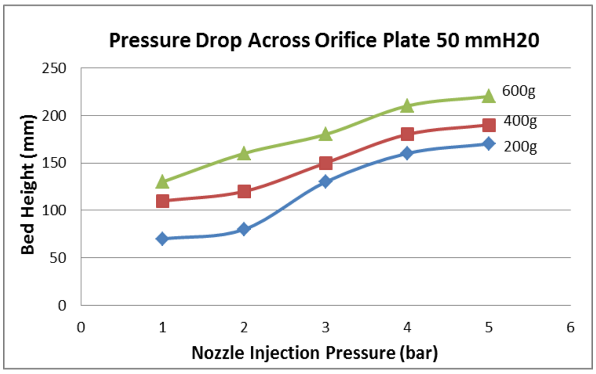
Figure-1. Schematic of the top spray fluidized bed column.

Both the top and bottom part of the fluidized bed column were secured with a 1.5 mm mesh to prevent the elutriation of the beads from the fluidized bed column. To monitor the pressure drop, a manometer was connected across the orifice plate and the fluidized bed column using transparent plastic tubes with valves. In this study, the orifice plate was used to measure the air flow rate from the blower. A fluid/air passing through the orifice constriction will experience a pressure drop across the orifice. This change can be used to measure the flow rate of the fluid. The fluidizing fluid was air from the surrounding environment. The fluidizing fluid can also be substituted with any other gas by connecting the desired gas cylinder to the air blower. Water at room temperature was used as the top spray liquid [8].

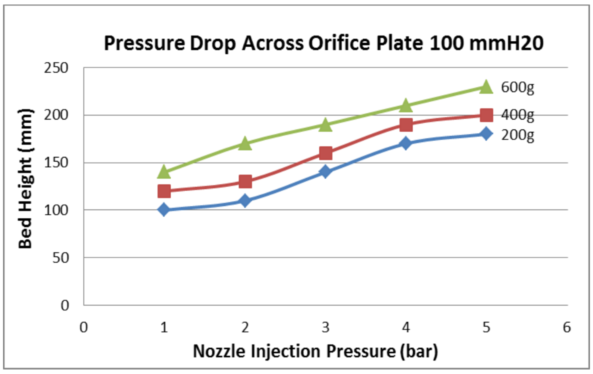
Different masses of beads (200, 400 and 600 g) were used as bed for the top sprayed fluidized bed column. The bed height was identified visually using a ruler. The pressure drops across the bed and orifice plate were measured by adjusting the valves on the transparent plastic tubes of the manometer. Air was supplied to the fluidized bed column at fixed flow rates of 50 mmH_2O, 100 mmH_2O and 150 mmH_2O. The desired air flow rate was achieved by adjusting the speed of the air blower. The bed was sprayed from the top with an axi-symmetric full cone nozzle of 1.19 mm inner diameter and 0.64 mm maximum free passage diameter. The nozzle was operated at injection pressures of 1 to 5 bar. A horizontal multi-stage chemical pump was used to serve the nozzle at different injection pressures. To avoid overloading and pump damaging situations, a return feed line was used to normalize the water flow. These experiments were conducted under ambient temperature conditions.

RESULTS AND DISCUSSIONS

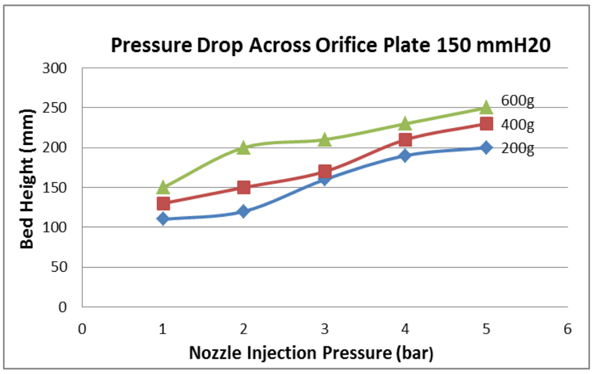
This study investigate the fluidized bed height at different air flow rates and water injection pressures. The change in bed state from settled to fluidized bed was studied by noting the change in bed height over the mass of beads.



(2a)



(2b)

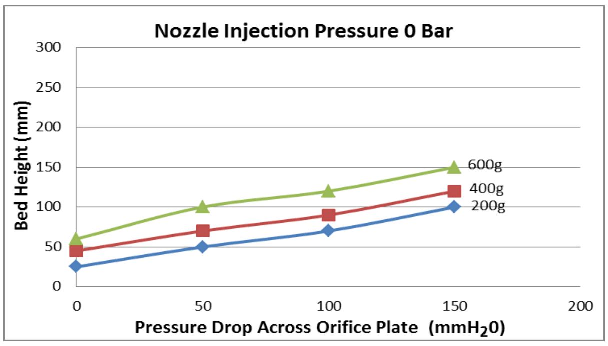


(2c)

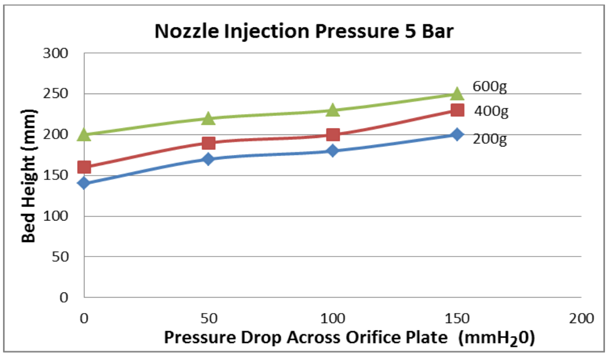
Figure-2. Fluidized bed height as a function of injection pressure.

Figures 2a, 2b and 2c show the dependence of the bed height on the nozzle injection pressure for various air flow rates. The fluidized bed height increased with injection pressure and pressure drop for all 200, 400 and 600 g of beads. The increase in bed height with injection pressure is attributed to the presence of the water in interstetial sites of the bed. A fluidized bed consists of fine particles compactifies when subjected to spray stress from the top [9].

The bed response depends on both the ambient pressure and spray stress. At high spray stress, the compaction is also higher and the interstitial air cannot flow through the bed. The interstitial air trapping can be investigated by measuring the air pressure just above and below the bed. The air pressure above the bed decreased abruptly with spray stress; however, an increasing trend in pressure was depicted just below the bed. This increasing pressure difference across the bed gives rise to a strong lifting force. The bed particles started to lift and barely fluidize, this condition is expressed in equation: $W_u = \rho_u A_u h(1-\varepsilon)$. In this equation, W_u is the mass of the bed particles, ρ_u is the density of the bed particles, A_u is the average cross-sectional area of the particles, h is the height of the settled bed and ε is the void fraction of the settledbed [10, 11].



(3a)

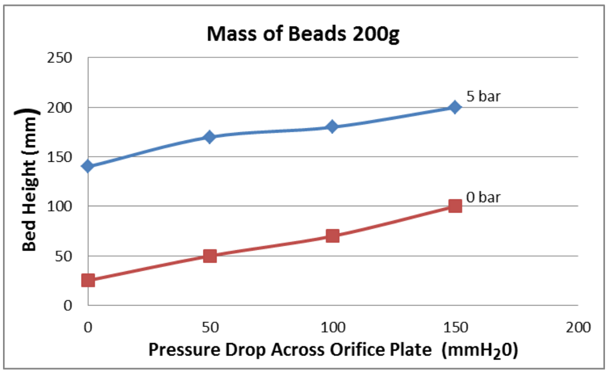


(3b)

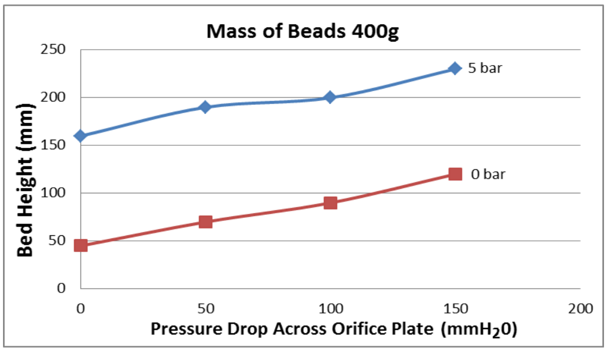
Figure-3. Bed height as a function of pressure drop with and without spray stress.

Figure-3 reports the bed height as a function of pressure drop with and without spray stress. It was noticed that the fluidized bed height increases with pressure drop [12]. Overal the height of the bed exposed to the top spraying was higher than that without spray stress. For instance, the height of the settled bed of 200 g beads was calculated as 140 mm, which was increased to 200 mm with pressure drop of 150 mmH_2O.Without top spray stress, the fluidized bed height at 0 mmH_2O was calculated as 25 mm, 45 mm and 60 mm for 200 g, 400 g and 600 g of beads, respectively. Under same operating conditions, the fluidized bed height with spray stress at the injection pressure of 5 bar was 140 mm, 160 mm and 200 mm for 200 g, 400 g and 600 g of beads, respectively.

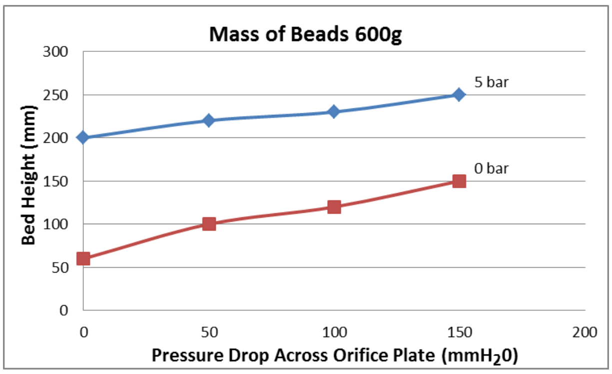
Figure-4 shows that the fluidized bed height not only depends on the pressure drop but also on the injection pressure. The results were compared at two injection pressures of 0 bar and 5 bar. The difference of bed heights with and without spray stress remained about 100 mm regardless of the bed weight. Overall the bed height with spray stress remained higher than that without spray stress.



(4a)



(4b)



(4c)

Figure-4. Comparison of bed height calculated with and without spray stress.

ARPN Journal of Engineering and Applied Sciences

CONCLUSIONS

This study investigated the response of the bed height to the air pressure drop and the water spray stress. The bed response was greatly influenced by the both the pressure drop and spray stress. At high spray stress, the bed compaction was also higher and the interstitial air cannot flow through the bed. The air pressure above the bed decreased abruptly with spray stress; however, an increasing trend in pressure was depicted just below the bed. This increased pressure difference across the bed strong lifted the bed to the incipient and then fully fluidized bed regime. This work concludes that the nozzle flow rate should be well optimized in the fluidized bed coating process to avoid the over-wetting, dry and wet quenching and elutriation of the particles from the bed.

ACKNOWLEDGEMENTS

This research project is partially funded by the long term research grant scheme (LRGS) of the Ministry of Higher Education Malaysia No. 15-8200-137-4-3.

REFERENCES

[1] F. Depypere, J.G. Pieter and K. Dewettinck. 2005. Expanded bed height determination in a tapered fluidized bed reactor. Journal of Food Engineering. 67: 353-359.

[2] K. Dewettinck and A. Huyghebaert. 1999. Fluidized bed coating in food technology. Trends in Food Science & Technology. 10: 163-168.

[3] B. S. V. S. R. Krishna.2013. Predicting the bed height in expanded bed adsorption column using R-Z correlation. Bonfring International Journal of Industrial Engineering and Management Science. 3(4): 107-110.

[4] M.Y. Naz, S. A. Sulaiman and B. Ariwahjoedi. 2013. Experimental study of airless spray jet breakup at elevated temperature and pressure. Applied Mechanics and Materials. 393, 711-716.

[5] F. Ronsse, J. G. Pieters and K. Dewettinck. 2008. Modelling side-effect spray drying in top-spray fluidised bed coating processes. Journal of Food Engineering. 86(4): 529-541.

[6] M.Y. Naz, S. A. Sulaiman, B. Ariwahjoedi and K.Z. K. Shaari. 2014. Characterization of modified tapioca starch solutions and their sprays for high temperature coating applications. The Scientific World Journal. 2014: 1-10.

[7] S. Pao, D. F. Kelsey and W. Long. 2009. Spray washing of tomatoes with chlorine dioxide to minimize Salmonella on inoculated fruit surfaces and cross-contamination from revolving brushes. Journal of Food Protection. 72(12): 2448-2452.

[8] B. Matthias, H. Thomas, G. Gunnar, P. Mirko and T. Evangelos.2014. Mixing and segregation in a bi disperse gas-solid fluidised bed: A numerical and experimental study. Chemical Engineering Science. 116: 317-330.

[9] M.Y. Naz, S.A. Sulaiman, B. Ariwahjoedi and K.Z.K. Shaari. 2015. Effect of pre-coat solution temperature on fluidized bed urea coatings. Surface Engineering. 31(7): 486-491.

[10] T. Homan, C. Gjaltema and D. V Meer. 2014. Collapsing granular beds: The role of interstitial air. Physical Review E. 89(5): 052204.

[11] Y. Suleiman, H. Ibrahim, N.V. Anyakora, F. Mohammed, A. Abubakar, B. O. Aderemi and P. C. Oonkwo.2013. Design and fabrication of fluidized-bed reactor. International journal of Engineering and Computer Science. 2(5): 1595-1605.

[12] M. Vanderroost, F. Ronsse, K. Dewettinck and J. G. Pieters.2012. Modelling the bed characteristics in fluidised-beds for top-spray coating processes. Particuology. 10(6): 649-662.