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Influence of Pressure Drop on the Performance of Multi-Stage Fluidisation System

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ABSTRACT

The term fluidisation refers to transforming a bed of particulate materials into a fluid by the action of a fluid passing across it. The use of an annular blade distributor known as a Swirling Fluidized Bed (SFB) in new applications may increase the efficacy of fluidisations on the bed. For this analysis, 30 blades were considered, and the results of varying the horizontal inclination angle of the blade distributors by 10, 12, and 15 degrees were analysed. The Computational Fluid Dynamics (CFD) simulation study was carried out in order to evaluate the pressure drop of the multi-stage fluidisation system could be evaluated. This research shows that a multi-stage fluidisation system results in energy conservation and maintains a highly efficient performance system. This research demonstrates that a 15° blade inclination angle with 30 blades may lower pressure without affecting performance, and for the velocity profile, it indicates velocity uniformity in fluidisation systems.

Keywords: Simulation and modelling, Fluidization system, Multi-stage Swirling Fluidized Bed (SFB), Pressure drop

1. INTRODUCTION

Fluidised beds have been used in chemical manufacturing for many years. This method is entirely compatible with the industrial combustion processes, solid fuel gasification, particle drying, particle heating, oxidation, metal surface treatment and catalytic and thermal cracking [1]. In addition, the airflow is a core medium to fluidise the bed in the fluidisation systems. Furthermore, the airflow must be enough force to fluidise or swirl the bed where the gas has passed through the gap of the annular blades' distributor [2]. The purpose of this research is to determine the applicability of multi-stage fluidisation systems on the pressure values at different stages of the swirling fluidised bed (SFB).

The pressure reduction of the distributor is significant since the airflow inside the fluidised bed will be calculated by that. The air reaches the bed in the lowest pressure drop zone if the pressure drop is very low, resulting in a non-uniform airflow distribution within the bed. In addition, designing a distributor is very critical. In the nature of conventional distributors, it is usually assumed that the pressure of the distributor reduces the ratio of the pressure [3-7]. The new type of fluidisation system (Swirling Fluidised Bed) can perform in low bed pressure depends not only on the type of distributor, as in Figure 1, but also on the fluidised particles, the depth of the bed, the velocity of surface gas, the aspect ratio of the bed and the tolerable percentage of uneven

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distribution [2]. Recent studies show that the operation is based on the simple theory where the horizontal movement of the bed particles is created by a horizontal portion of gas velocity in the bed. This low elutriation also leads to cyclone-like characteristics resulting from the swirling movement of bed particles. Therefore, very fine particles and a wide range of particle shapes can be fluidised in this kind of fluidised bed.

The flow systems in SFBs involve minimal fluidisation of packed beds, swirling regime, two-layer operation, and eventually elutriation or transport. Thus the actions of the bed can be summarised as [7]: (i) the pressure drop of the swirling fluidised bed rises with the mass flow of fluidisation gas, (ii) Larger particles have a lower drop in pressure and can handle a higher speed on the surface, (iii) increased overlap of the distributor blades allows the flow of more condenser air, allowing a higher drop in pressure. The swirling field also decreases elutriation. For example, the particle size, bed weight and the number of blades are the most significant variables affecting bed behaviour. The gas is longer than the surface height due to the helical, so particle diffusion does not depend on the bubbles. The gas is wholly distributed into the bed at the first stage in the swirl area [8]. Compared to the old, fluidised bed, the bed pressure drops after on top of twist surface velocity also increased minimal fluidisation, discovered from previous research [2]. This condition has the potential to produce a bubble inside the beds. These results will be observable in a low-energy-consumption fluidisation system. Therefore, this study aims to investigate the pressure drop at different stages of SFB to determine whether the second stage of SFB has the same velocity capability.

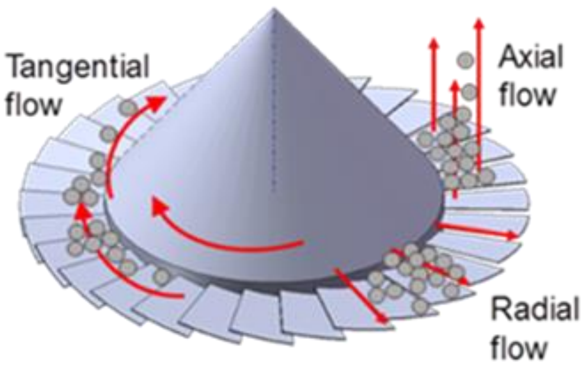

Figure 1: The annular blades distributor in Swirling Fluidised Bed.

2. MATERIAL AND METHODS

In the new approach of multi-stage fluidisation systems, Computer Fluid Dynamics (CFD) is used to analyse airflow propagation. The use of selected software applications, such as SolidWork, ANSYS etc., would assist in the study. Computer-aided modelling (CAM) like SolidWorks is used to construct a novel fluidisation system design with two characteristics that significantly impact airflow distribution. The first is an axial entry plenum chamber, and the second is a distributor parameter with different angles. Several boundary conditions are applied to the model, as shown in Figure 2, velocity inlet, outflow, and wall. The condition of the boundary type was described in the application of ANSYS Fluent.

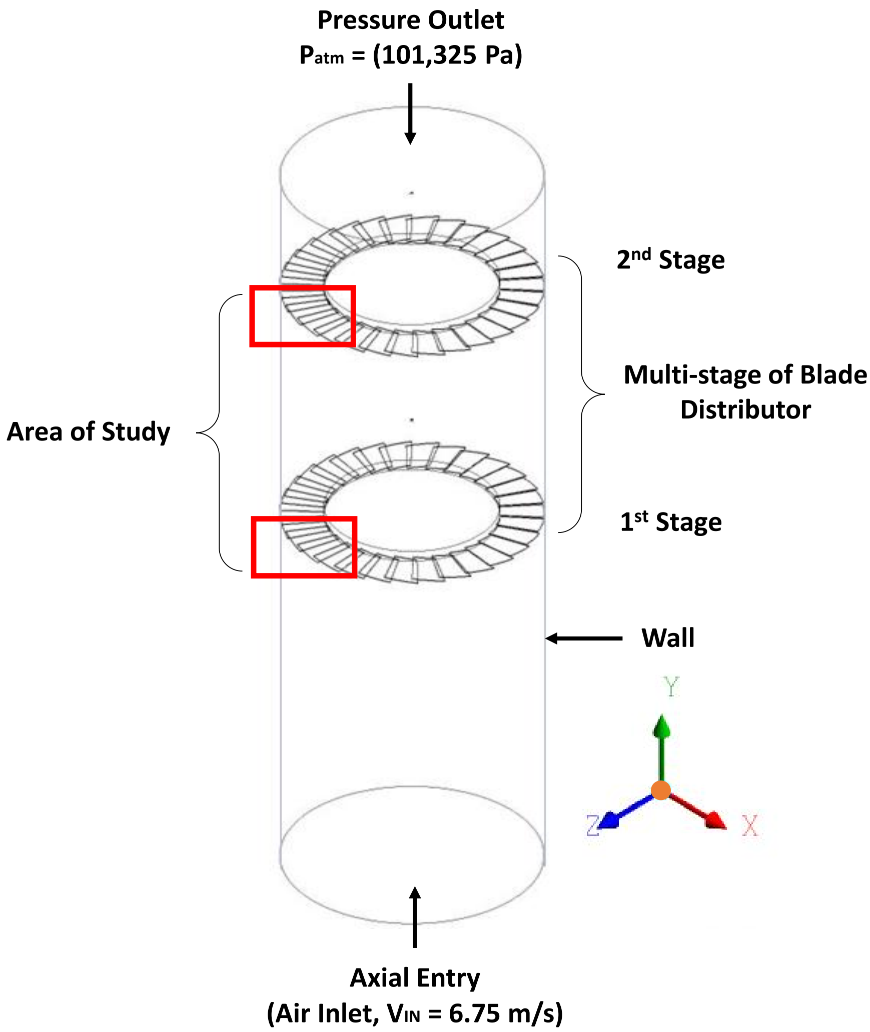

Figure 2: Boundary condition of Multi-stage Swirling Fluidized Bed (SFB).

2.1 Simulation and Modelling Set-Up

In order to verify the numerical approaches, many experimental systems are researching and analysing the flow of the fluidised bed of particles [7]. Numerical simulations are chosen to depict experimental data accurately. The same conditions as previous researchers [5-7] have been implemented in the present study. The Tri: Pave Meshing Scheme was used on the surface to construct a face mesh comprising irregular triangular mesh elements. The meshing algorithm was specified for Tet/Hybrid parameter form, specifying tetrahedral, hexahedral, pyramidal and wedge elements. The turbulence model of RNG $k-\varepsilon$ has been set for simulating the turbulence flow in the SFB. The Reynolds Averaged Navier Stokes (RANS) turbulence equation of the (Re-Normalization Group) RNG methods based on model transport equations for the turbulence kinetic energy (k) and its dissipation rate (ε), which is RNG $k-\varepsilon$ model has been selected [4]. A second-order upwind scheme was chosen to discretise the momentum equations to minimise numerical diffusion [9-10]. This turbulence model is very similar to that of the semi-empirical model $k-\varepsilon$. However, it has an extra term in its dissipation rate (ε) equation which significantly improves the precision for quickly strained flows [9-11].

3. RESULTS AND DISCUSSION

Many previously conducted experimental systems analysed the flow of the fluidised bed of particles in order to validate the numerical approaches. As numerical simulations can accurately represent the outcomes of experimental activity, a numerical approach is selected. The data was collected on a horizontal plane, 10 mm above the distributor at each stage of the fluidisation system, as this was the ideal place to investigate the airflow characteristics.

3.1 Effect of Pressure Drop at Different Stage Fluidisation

The pressure drop is a significant factor that needs to be addressed in the fluidisation system because it can affect the airflow distribution and the physical properties of the bed. The larger the pressure drop in fluidisation systems, the more energy is required to maintain the appropriate process flow, necessitating more energy to transfer the required quantity. On the other hand, a fluidisation system may utilise a lesser energy power if the pressure drop is modest. Therefore, the required quantity of energy was quite close to what was anticipated. An acceptable range of the lowest pressure drop via blade configuration can also maximise energy consumption for bed characteristics. Therefore, the data were taken at each stage of fluidisation systems, 10 mm above and lower the blades distributor. For blade number 30 through different horizontal inclination angles (10°, 12° and 15°), the pressure drop relation is shown in Table 1 and Figure 3 below. It is important to avoid high-pressure drops because the fluidisation systems can lead to additional power needed to operate SFB processes. As for the results in Table 2 at different stages of blade distributor (multi-stage), the velocity distribution plays a vital role in influencing pressure reduction. Moreover, the kinetic energy of the flow would reduce, similar to the theory of gravity.

Table 1: Cases of parametric study on the multi-stage swirling fluidised bed (SFB).

Case	Number of Blades	Horizontal Inclination Angle	Types of Plenum Chamber
1		10°	
2	30	12°	Axial Entry Plenum Chamber
3		15°	

Table 2: The pressure drops of blades number 30 via different inclination angles of 10°, 12° and 15°.

Number of Blades	Inclination Angle	Average Pressure Drop First Stage Blade (Pa)	Average Pressure Drop Second Stage Blade (Pa)
	10°	4909.22	573.61
30	12°	2945.40	479.17
	15°	1597.84	394.67

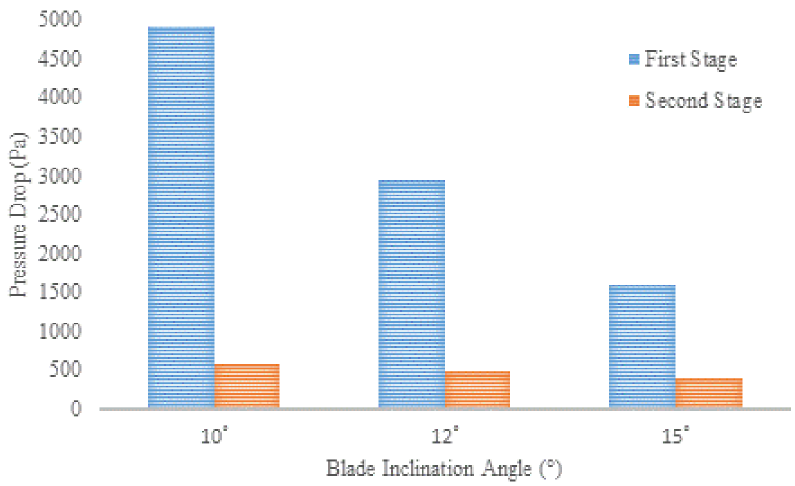

Figure 3: Influence of different inclination angles towards multi-stage fluidisation system.

4. CONCLUSION

The CFD analysis is a crucial way of understanding SFB's dynamic airflow phenomena, which have all three components of velocity: axial, tangential and radial. These velocity components demonstrate that excellent mixing may be achieved in a fluidised bed system operating with an annular blade distributor and a sufficient distributor pressure drop. Based on the existing design, it was determined that the distributor with 30 blades and a 15° inclination is optimal in terms of tangential and axial flow uniformity and minimal pressure drop. The current study confirmed the findings that even though it has been said that a specific type of fluidisation system is the most effective, high-pressure drop still forces in SFB when using a blade distributor.

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REFERENCES

[1] Mohideen, M. F., Sreenivasan, B., Sulaiman, S. A., & Raghavan, V. R. Heat transfer in a swirling fluidised bed with geldart type-D particles. Korean Journal of Chemical Engineering, vol 29, (2012) pp. 862-867.

[2] Mohideen, M. F., & Raghavan, V. R. Experimental studies on a swirling fluidised bed with annular distributor. J. Appl. Sci., vol 11, issue 11 (2011) pp. 1980-1986.

[3] Zainuddin, H. H. M., Nawi, M. A. M., Kasim, M. S., Hazwan, M. H. M., Mustafa, W. A., Noriman, N. Z., & Dahham, O. S. Determination of moisture content on kenaf via fluidisation systems. In AIP Conference Proceedings, vol. 2213, No. 1 (2020) p. 020271.

[4] Zainuddin, H. H. M., Nawi, M. A. M., Kasim, M. S., Hazwan, M. H. M., Mustafa, W. A., Noriman, N. Z., & Dahham, O. S. Studies on characteristic of glycerol-kenaf pellet via fluidisation drying process toward energy produced. In AIP Conference Proceedings, vol 2213, issue 1 (2020) p.020276.

[5] Nawi, M. A. M., Amin, M. R., Kasim, M. S., Izamshah, R., Ishak, M. I., Khor, C. Y., ... & Syafiq, A. M. The influence of spiral blade distributor on pressure drop in a swirling fluidised bed. In IOP Conference Series: Materials Science and Engineering, vol 551, issue 1 (2019) p. 012106.

[6] Abd Latif, M. L., Nawi, M. A. H. M., Mustafa, W. A., Sarip, M. S. M., Jamlos, M. A., Ahmad, M., ... & Hussein, H. Numerical analysis of velocity magnitude in a swirling fluidised bed with spiral blade distributor. Journal of Advanced Research in Fluid Mechanics and Thermal Sciences, vol 59, issue 1 (2019) pp. 38-44.
[7] Ashri, S.F., The Effectiveness of Multi-Staged Swirling Fluidized Bed. B. Eng. Disser-tation. Unversiti Teknologi PETRONAS. Tronoh, Perak (2012).
[8] Nawi, M. A. M., Ishak, M. I., Rosli, M. U., Musa, N. M., Termizi, S. N. A. A., Khor, C. Y., & Faris, M. A. The effect of multi-staged swirling fluidised bed on air flow distribution. In IOP Conference Series: Materials Science and Engineering, vol 864, issue 1 (2020) p. 012194.
[9] Versteeg, H.K., and Malalasekera, W., An Introduction to Computational Fluid Dynamics (Essex:Pearson) (2007).
[10] Nawi, M.A.M., Aerodynamics of a Swirling Fluidized Bed. Master Thesis: Universiti Tun Hussein Onn Malaysia. (2013).
[11] Hanzah, M. R. B., Rahim, W. M. F. W. A., Khor, C. Y., Ishak, M. I., Rosli, M. U., Jamalludin, M. R., ... & Nawi, M. A. M. New approach for quality control in manufacturing process. In AIP conference proceedings, vol 1885, issue 1 (2017) p. 020069.