Feasibility study on pliant media drying using fluidized bed dryer

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Abstract. The usage of pliant media for blasting in surface preparation has gained substantial interest in various industries, particularly oil and gas. Being a clean technology, this relatively new method of surface preparation has become an alternative to conventional abrasive blasting technique which lowers fugitive emissions from blasting process and hence lowering risk to workers in the industry. Despite proven to be effective and cost efficient, the usage of pliant media in tropical climate poses a new challenge due to the torrential rain in the monsoon season. During rainy and wet conditions, the pliant media was literally soaked and the recovery rate of the pliant media for a continuous blasting becomes retarded. A viable technique for drying of this pliant media has then become imperative. The present study proposes to dry water laden pliant media in a Swirling Fluidized Bed Dryer (SFBD). In this preliminary study, three bed loadings of 1.7, 2.0 and 2.3 kg of pliant media was dried in the SFBD at 80°C, 90°C and 100°C. The experimental works revealed that the SFBD has shown excellent potential to dry the pliant media with a relatively short drying time. The behaviour of moisture ratio and drying rate against time are discussed. The findings conclude that the SFBD is a feasible technique for wet pliant media drying and can be extended for continuous processing system.

Keywords: Pliant media drying, Swirling Fluidized Bed Dryer (SFBD), moisture ratio, drying rate

1. Introduction
Surface preparation using pliant media is gaining substantial interest in many industries in Malaysia where process is required on annual basis, such as the oil rig platform, material processing plants and during maintenance of heavy machines. Unlike traditional practice in surface preparation where abrasive materials were used, utilization of pliant media results in reduction of air borne dust to almost 99% [1]. Hence, operator gains better visibility during blasting, especially while working in constrained areas. More importantly, the physically soft blasting medium ensures less rebound energy which reduces surfaces damages especially sensitive ones. As a result, overall productivity of blasting was increased while less impact on the environment was produced.

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The concept of pliant media blasting is shown in Figure 1. First, high pressure air from compressor was directed into the blasting nozzle containing pliant media. When this blasting nozzle was directed towards the surface to be prepared, the pliant media was released at high velocity. As a result, the chunks of pliant media hit the surface, and transfer the impact energy. In a matter of few microseconds, the pliant media flattens and suppresses the surface to scrap the unwanted surface before falling on the ground with the debris.

![Figure 1. The pliant media blasting concept.](image)

Despite the benefits and efficiency of the blasting process, pliant media is strictly limited for usage on dry conditions only. Being very high in porosity, the pliant media readily absorbs moisture hence prohibiting the usage in wet conditions. These limitation causes surface preparation during monsoon season becomes very difficult and challenging as blasted pliant media could not be recycled readily before drying. Currently, operators use large inventory of dry pliant media for surface preparation in wet conditions since wetted media cannot be used in the existing equipment. This leads to loss of precious operation time as well as increase in pliant media usage. Treating this drawback as a problem to solve, the present study explores the feasibility of using a Swirling Fluidized Bed Dryer (SFBD) to dry the wetted pliant media. Batch experiments were conducted using three bed weights of 1.7 kg, 2.0 kg and 2.3 kg at three drying air temperatures of 80°C, 90°C and 100°C. Prior to this, the hydrodynamics of the SFBD operating with pliant media was investigated. Regimes of operation were classified and minimum fluidization velocity, $U_{mf}$ were recorded.

2. The swirling fluidized bed dryer (SFBD) system

The swirling fluidized bed (SFB) dryer which was proposed in this study for pliant media drying, is a relatively new method in drying. The SFBD system was made by an array of 60 blades which resembles a stator configuration in a gas turbine system. These blades which were inclined at 12° from the horizontal plane form an annular bed as a centre body is placed in the core of the system as shown in Figure 2.
The centre body was necessary to avoid dead zone in the bed [3]. When hot air flows through the inclined distributor, two jet velocity components created in the bed; the vertical component which fluidizes the bed while the horizontal component which induce swirling. The magnitude of each component depends on the blade inclination. Lower blade angles were preferred as they provide larger horizontal momentum and hence faster swirling with reduced elutriation due to smaller vertical momentum [3,4]. Previous study by [4 – 6] reported that there can be three or four operational regimes in this bed. The most apparent of this bed is its low distributor pressure drop and vigorous mixing during operation. A study on wheat grains due to swirling effect in fluidized bed dryer (FBD) was reported by [7]. Moisture extraction rate and dryer efficiency were increased when swirl motion up to 5-25% and 38% when compared with non-swirl motion. Thomas and Varma [8] studied the drying behaviour of granular materials experimentally for different temperatures, velocity, particle sizes and mass of solids and concluded the critical moisture content was depending on all the experimental parameters especially temperature. Abid et al [9] studied the effect of humidity and velocity on corn kernels drying rate and reported both effects were less significant in comparison to drying temperature. In this study, batch experiments were conducted using three bed weights of 1.7 kg, 2.0 kg and 2.3 kg at three drying air temperatures of 80°C, 90°C and 100°C. Prior to this, the hydrodynamics of the SFBD operating with pliant media was investigated. Regimes of operation were classified and minimum fluidization velocity, \( U_{mf} \) were recorded.

3. Methodology
Experiments were started with loading column or drying chamber or bed with wet sponge media with 30% till 40% moisture content. Then, frequency converter (model Holip-HL PA07543B) was switched on to supply air flow and must satisfy the required flowrate for \( U_{mf} \) for each loadings. The air flow were accelerated to the SFBD system by blower and heated by electrical heater. This means that, hot jet air flows were used to dry the sponge media which following prepared design of experiment as shown in Table 1. About 3 – 5 grams of the sponge media samples were taken from the bed and were weighed using electronic weight balance model Perkin-Elmer with an accuracy of \( \pm 10 \) mg before putting it into industrial oven model Memmert to dry the samples at 105°C. The samples were taken at 0th until 20th minute with 2 minutes time interval. After 3 hours, the samples were taken out from the oven and were weighed once again to determine the samples final weight. Figure 3 shown the schematic diagram of the experimental and SFBD setup while Table 1 below shown the design of experiment in order to conduct the experiments.
Table 1. The pliant media drying experiment parameters.

| Temperature, T (°C) | Weight (kg) | Minimum Fluidization Velocity, $U_{mf}$ (m/s) |
|---------------------|-------------|---------------------------------------------|
| 80, 90, 100         | 1.7         | 1.25                                        |
|                     | 2.0         | 1.29                                        |
|                     | 2.3         | 1.37                                        |

4. Results and discussion

4.1 Hydrodynamics of pliant media

Hydrodynamic characteristics are important to be determined in any system involving as it gives an insight to the system behaviour as well as its resistance on flow. Both of this finding are useful in estimating the system’s performance as well as related cost involved, which will finally analyzed through benefit-cost analysis. In the present study, three most important hydrodynamic characteristics are studied, namely the distributor pressure drop, $\Delta P_d$, bed pressure drop, $\Delta P_b$, and minimum swirling velocity, $U_{ms}$. $\Delta P_d$ indicates the amount of kinetic energy loss (converted the potential energy) when the system operates without any pliant media inside (base resistance towards flow) as presented in Figure 4. From the figure, the $\Delta P_d$ for the SFBD increases exponentially with superficial velocity which is typical for fluidized bed’s distributor. The interesting finding however, is the magnitude of pressure drop which is relatively smaller in comparison with conventional distributors. For instance, Agarwal et. al [11] proposed that $\Delta P_d$ should never be less than about 3400 Pa are required to ensure good fluidization characteristics. In the present study, the highest recorded value of $\Delta P_d$ yet capable of providing desired fluidization condition.
Apart from $\Delta P_d$, $\Delta P_b$ and $U_{mf}$ in are shown in Figure 5 where $\Delta P_b$ is plotted against superficial velocity. In the packed condition (region I), $\Delta P_b$ increased exponentially before achieving $U_{mf}$ condition in region II at about 1.25 m/s. The exponential trend is because the pliant media is made by coarse particles and thus large voidage between particles. As a result, the flow inside the voidage becomes turbulent and resulting the exponential trend, as discussed by [10].

Upon $U_{mf}$, pressure fluctuations are recorded in region II where random bubbles were observed. Increasing the superficial velocity of air even further, the whole begins to swirl as a single mass at about $V_s = 2.15$ m/s and finally elutriation occurred beyond $V_s = 2.52$ m/s.

The regimes of operation are constant and changes as the particle becomes lighter and lighter caused by continuous drying process acting on it. The differences of swirling pattern were caused by the weight changes with the respected to the time. The swirling patterns observed such as below [3,5]:

a) Bubbling: in the beginning of the drying process, after packed condition, the bed was to have small bubbles at certain location and the bubbles grow at this location only with the increase in the drying air flowrate. This phenomena is known as channelling as per described by [10].
b) Two layer fluidization: at this phase, lower layer particle having swirling motion while upper layer still having bubbling condition. At this regime, velocity tangential velocity component was decayed and at certain height, it is insufficient to create any swirling in the bed.

c) Fully swirling: when the particle becomes drier, stable swirling pattern was finally reached. In this phase, swirling velocity eventually becomes higher as a result of lower bed weight as a result of continuous moisture transfer.

4.2 *Moisture ratio and drying rate*

![Figure 6](image)

**Figure 6.** Temperature comparison of moisture ratio versus drying time for 2.0kg bed loads.

Figure 6 above shown temperature comparison between 80°C, 90°C and 100°C of moisture ratio against drying time for 2.0kg bed loads graph. The plotted graph has shown that, higher temperature extracted more moisture from the particle than less temperature. The plotted graph in the figure has shown most contrast comparison started 6th minute till the particle have moisture loss. In short, hotter air flow leads to the higher moisture loss of the sponge media. Apart from that, fast moisture removal was observed for all drying temperatures, with typical drying type of about 10 minutes for all drying temperatures. This is due to the high porosity of the sponge media apart from good contact with air through vigorous mixing in the bed. The drying rate however, remained almost steady throughout the drying process. The total drying time was ideal for actual industrial process which requires rapid drying to ensure high productivity in the surface preparation processes.

4. Conclusion

Experimental results and discussion proves that the capabilities of drying the sponge media through SFBD method. It also shown that drying the particle became faster when higher temperature was used. In the other hand, the sponge media swirling pattern depends on the particle moisture content. The bed undergoes several notable regions, designated at the packed region, minimum fluidization, swirling region and finally elutriation.

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6. References

[1] http://www.spongejet.com/index.php (accessed: 23/03/2014)
[2] Mohideen M F, Sreenivasan B, Sulaiman S A and Raghavan V R 2012 Heat Transfer In A Swirling Fluidized Bed With Geldart Type-D Particles *Korean J. Chem. Eng.* **29**(7) 862-867
[3] Mohideen M F, Faiz M, Salleh H., Zakaria H and Raghavan V R 2011 Drying of Oil Palm Frond via Swirling Fluidization Technique Proc. of World Congress on Engineering 3 2375-2380

[4] Mohideen M F, Md Seri S and Raghavan V R 2012 Fluidization of Geldart Type-D Particles in a Swirling Fluidized Bed Applied Mechanics and Materials 110-116 3720-3727

[5] Kaewklum R and Kuprianov V I 2010 Experimental Studies on a Novel Swirling Fluidized Bed Combustor Using an Annular Spiral Air Distributor Fuel 89 43-52

[6] Shu, J, Lakshmanan, V I and Dodson CE 2000 Hydrodynamic Study of a Toroidal Fluidized Bed Reactor Chemical Engineering and Processing 39 499-506

[7] Özbey M and Söylemez M S 2005 Effect of Swirling Flow on Fluidized Bed Drying of Wheat Grains Energy Conversion and Management 46 1495-1512

[8] Thomas P P and Varma YBG 1992 Fluidized Bed Drying of Granular Food Materials Powder Technology 69 213-22

[9] Abid M, Gilbert R and Laguure C 1990 An Experimental and Theoretical Analysis of the Mechanisms of Heat and Mass Transfer During the Drying of Corn Grains in a Fluidized Bed International Chemical Engineering 30(4) 632-42

[10] Kunii D andLevenspiel O 1991 Fluidization Engineering, 2nd Ed. Butterworth-Heinemann

[11] Agarwal, J C, Davis, W L and King, D T 1968 Fluidized-bed coal dryer Chemical Eng. Proc. 58 85