Proceedings of the International Conference on Islamic Civilization and Technology Management
Editors: Syahrul Fahmy, Syed Hadzrullathfi Syed Omar, Nabihah Abdullah, Rabiatul Manisah Mohamed

e-ISBN 978-967-2231-26-4

EXPERIMENTAL STUDY OF AIRBORNE DUST GENERATION DURING POWDER FREE FALLING

*Nur Anis Liyana Azhar & Siti Ilyani Rani**
ilyani@tatiuc.edu.my

Faculty of Chemical Engineering Technology, TATI University College, Jalan Panchor, Teluk Kalong, 24000 Kemaman, Terengganu, Malaysia

ABSTRACT

Powder handling produces airborne dust to the surrounding that can poses various hazards to peoples, industrial facilities and environment. This paper describes an experimental set up to examine the airborne dust generated in free falling of powders from a conveyor belt and investigates the influence of particle properties on the drop heights and conveying velocities to the formation of airborne dust. For this purpose a dust generation measurement device was fabricated to quantify the amount of the airborne dust. It is found that the powder properties, drop height and conveying velocity have strong influence to the amount of airborne dust generated during free falling.

1. INTRODUCTION

The storage, handling and transportation operations of bulk solids involving a falling stream of powder are very common in agriculture industry. In such operations, the discharge bulk powder from hopper or belt conveyor will trigger fine particles contained in the free fall powder break away from the main stream and become mixed with surrounding air causing airborne dust. Such dust emissions contaminate ambient air while the bulk powder is being moved by equipment. This phenomena can cause a number of problems in industry such as risks for operator's health, facilities hygiene and dust explosions.

The relative motion between the particles and surrounding air is the fundamental mechanism during particle-air interaction. Besides gravitational force, the moving particles are also affected by drag force. The collisions between particles may occur due to the unspherical shape and irregular size during free fall. The escaped particle and the entrained ambient air form a boundary layer surrounds the core of the main stream. The boundary layer will expand with increasing drop height due to the the turbulent motion of the surrounding air causes the smaller particles to occupy the boundary layer of the falling stream.

Numerous studies have attempted to measure the dust generation rate during the material free falling process by several factors, such as the drop height, mass flow rate, moisture content and particle size [1-5]. Several studies investigating the methods to control dust emission in industries have been carried out on [6-8]. In another study, Waduge et al. utilised a single camera and a laser to capture the airborne wood dust generated in different areas of the silo [9]. Rani et al. performed numerical analysis to investigate the dust emission from bulk solid during free fall using Computational Fluid Dynamics (CFD) [10]. The numerical study using coupled Discrete Element Method (DEM)/Computational Fluid Dynamics (CFD) was used by Daniel et al. to examine the dust release from bulk solid during handling [11].

The dispersion of fine particles in air is a complex mechanism due to the powder properties and characteristics. Therefore, understanding the knowledge of the mechanisms of dust generation during powder free fall and how much dust is generated are crucial in designing the dust control system.

The present paper evaluates the dust generation rate of four types of agricultural powder at different drop heights and conveying velocities. The dust generation rate is compute quantitatively using the formula by Plinke et al. [3]. The results of this study can be used in providing references and knowledge in airborne dust generation in agriculture powder handling.

2. MATERIAL AND METHODS

Figure 1 shows the apparatus used to measure the amount of airborne dust generated. This apparatus has two sections: the dust generation section on the left and the dust measurement section on the right. A conveyor system fed the material at a specific rate into the dropping zone. Dust was drawn into the measurement section by air entrained during the material fall. The amount and of the airborne dust generated were measured in a four-stage impactor located at the top of dust measurement section. Each material was dropped from the end of a conveyer belt at height of 0.6 m, 0.9 m, and 1.2 m. Three conveying velocities are used, 0.1 m/s, 1.5 m/s and 2.5 m/s. The total mass dropped for each experiment was 1000 g.

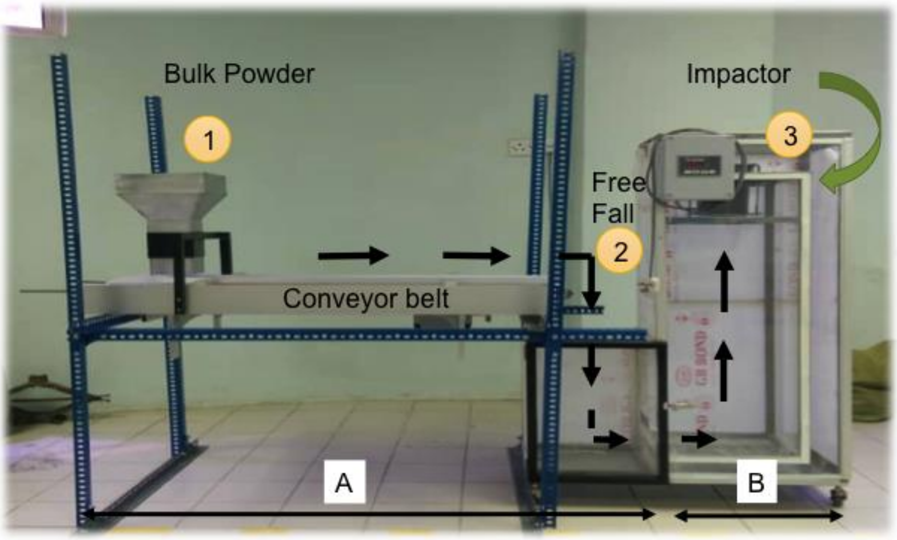

Figure 1. Dust generation experimental apparatus. A) Dust Generation Section B) Dust Measurement Section.

2.1. Materials

Four types of agricultural powder (castor sugar, oat, semolina and tea) were used in the experiment and the properties are summarised in Table 1. The shape of particles are shown in Figure 2.

Table 1. Powder properties.

Powder	Shape	Bulk Density (kg/m^3)	Size (µm)
Castor Sugar	Crystalline	891.2	336.3
Oat	Flaky	273.0	423.4
Semolina	Aggregated	734.1	598.1
Tea	Irregular	416.4	267.1

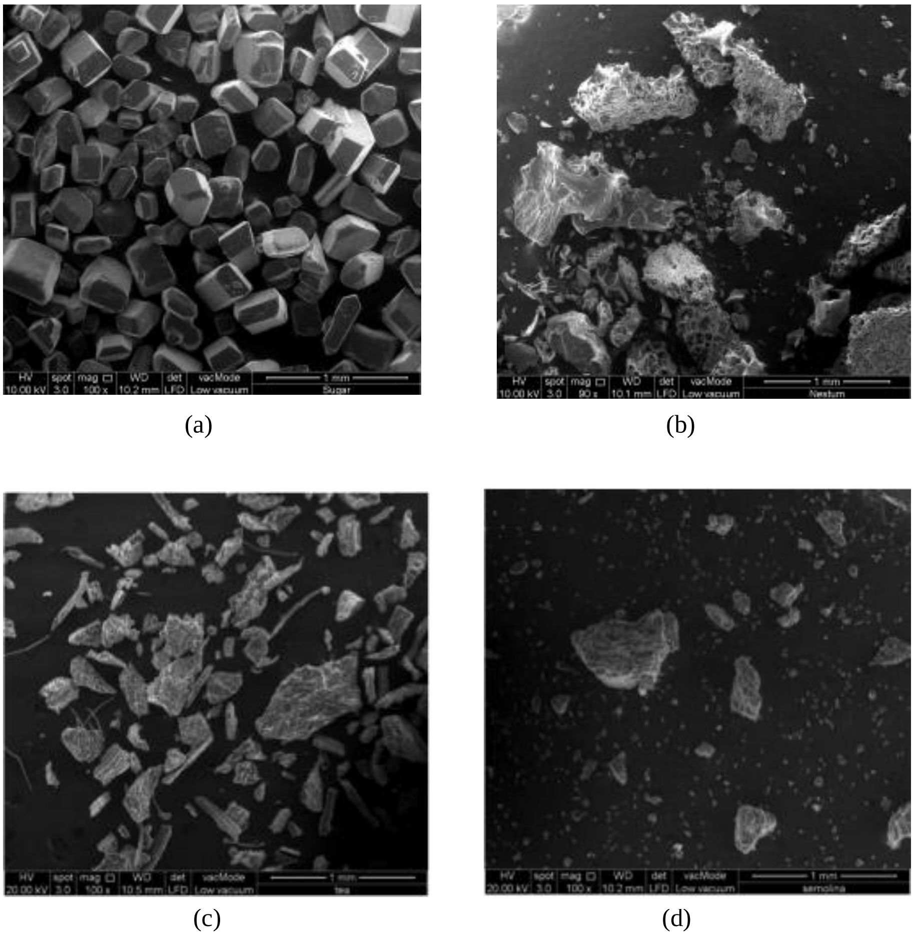

Figure 2. Scanning electron microscope (SEM) image of (a) Castor sugar (b) Oat (c) tea (d) semolina.

2.2. Airborne Dust Measurement

In current study, the dustiness of material is used to measure the airborne dust generated during free fall. The dustiness is calculated using Equation 1 without consideration the size distribution of the original material or the size distribution of the dust generated [3].

$$G = \frac{M_D}{M_M} \qquad (1)$$

where, G is the ratio of the total mass of dust collected in the impactor to the total mass of material tested, MD is the mass of dust generated and MM is the total mass of test material.

3. RESULTS AND DISCUSSION

In this study, the main influence factors on the dust cloud generation, such as the particle characteristics, drop height and conveying velocity have been investigated experimentally. During powder free fall, the interparticle distance is small and the drag forces acting on either side of a particle are different. The particle, therefore tends to rotate because of a pressure gradient and pulls away from the core of the stream to the ambient air when the drag force achieves a certain strength Also, when a particle stream drops onto a contact surface, the trapped air is released and the fine particles of the entrainment flow then re-suspension and re-dispersion with a certain initial impact velocity. The rate of airborne dust generation is called the total dust rate, which relates to the falling, collision and impaction processes.

3.1. Influence of Drop Heights

Figure 3 shows the influence of drop heights on airborne dust generation. Increasing drop height increased the impaction for all materials, hence generate more dust to the surroundings. Tea powder generates the highest airborne dust at all drop heights followed by oat, semolina and castor sugar. The impacting velocity of particles increases with increasing drop height, and the re-suspension and re-dispersion dust driven by the entrained air increases after impacting the contact surface, which results in increasing airborne dust generation. Also, the inter-particles distance increases with increasing the conveying rate and drop height, thus more particles are pulled away from the core stream to the surronding.

Powder properties play an important role in fine dust generation. Irregular shape of tea powder generate more fine dust due to the particle collisions in the core stream. Although the bulk density of tea is heavier than oat, higher airborne tea dust is generated due to the smallest particle size. Small particle size will generate more airborne dust due to the terminal velocity. The mean particle size of castor sugar is smaller compared to oat and semolina, however generates the lowest airborne dust due to the highest bulk density.

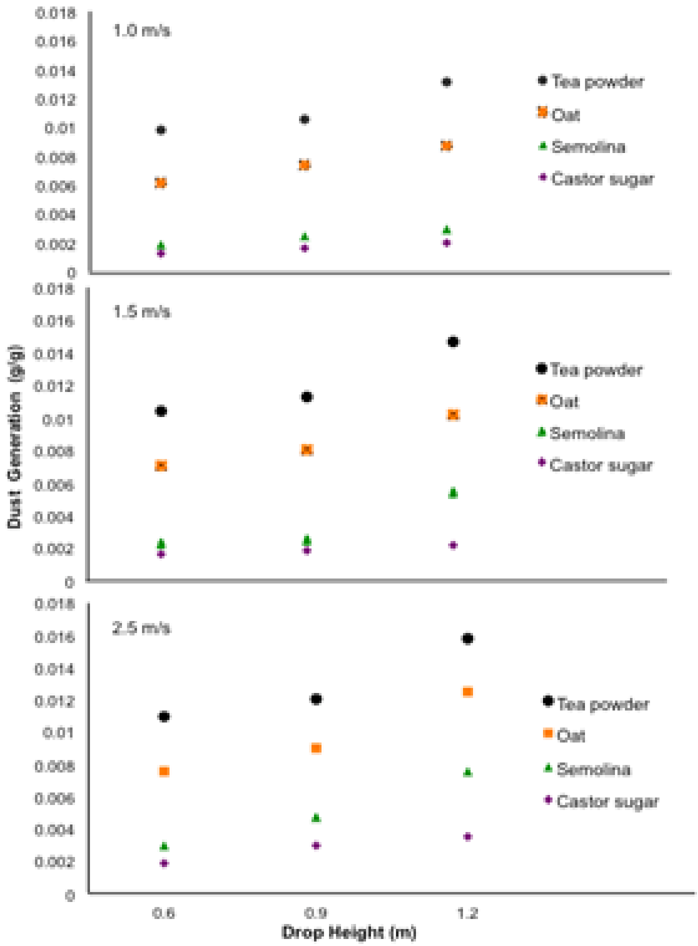

Figure 3. Influence of drop heights and conveying velocities on airborne dust generation

3.2. Influence of Conveying Velocities

Figure 3 also portrays the influence of conveying velocities on airborne dust generation. Increasing conveying velocities increased the inter-particles collisions during free fall and force more particles to break away from the core stream to the surroundings. Increasing the conveying velocities will increase the airborne dust generation. The influence of powder properties is as discussed in 3.1.

4. CONCLUSIONS

This paper presented an experimental investigation on dust generation rates of a free-falling particle stream of four types of agricultural powder. The results of this investigation show that the airborne dust generation increased as the drop height and conveying velocity increased. Powder properties significantly affected the dust emssions to the surrounding, therefore increase the airborne dust generation. The present study, however, makes several noteworthy contributions to assist powder handling facilities in controlling dust emission.

ACKNOWLEDGEMENTS

The authors fully acknowledged Ministry of Education for the approved fund (FRGS/1/2015), University College TATI (UC TATI) for the support which makes this important research viable and effective.

REFERENCES

[1] Plinke, M. A., Leith, D., Holstein, D. B., & Boundy, M. G. (1991). Experimental examination of factors that affect dust generation. The American Industrial HygieneAssociation Journal, 52(12), 521–528.

[2] Plinke, M. A., Maus, R., & Leith, D. (1992). Experimental examination of factors that affect dust generation by using Heubach and MRI testers. The American Industrial Hygiene Association Journal, 53(5), 325–330.

[3] Plinke, M. A., Leith, D., Boundy, M. G., & Löffler, F. (1995). Dust generation from han-dling powders in industry. The American Industrial Hygiene Association Journal, 56(3), 251–257

[4] Duana, M., Wang, Y., Ren, X., Qu, X., Cao, Y., Yang Y., & Nian, L. (2017). Correlation analysis of three influencing factors and the dust production rate for a free-falling particle stream. Particuology, 34, 126-133

[5] Chakravarty, S. (2019). Towards a theoretical understanding of dustiness. Granular Matter, 21, 97.

[6] Tooker, G. E. (1992). Controlling fugitive dust emissions in material handling operations. Bulk Solids Handling, 12(2), 227–232.

[7] Wypych, P., Cook, D., & Cooper, P. (2005). Controlling dust emissions and explosion hazards in powder handling plants. Chemical Engineering and Processing: Process Intensification, 44(2), 323–326.

[8] Ansart, R., De Ryck, A., & Dodds, J. A. (2009). Dust emission in powder handling: Free falling particle plume characterisation. Chemical Engineering Journal, 152(2),415–420.

[9] Waduge, L. L. L., Zigan, S., Stone, L. E., & Belaidi, A. (2016). Predicting concentrations of fine particles in enclosed vessels using a camera based system and CFD simulations. Process Safety and Environmental Protection, 5, 262–273.

[10] Rani, S. I., Aziz, B. A., & Gimbun, J. (2015). Analysis of dust distribution in silo during axial filling using computational fluid dynamics : Assessment on dust explosion likelihood. Process Safety and Environmental Protection, 96, 14–21.

[11] Daniel, S., Nadja, S., Eberhard, S., Raimondas, J. & Harald, K. E. (2019), Investigation of the dust release from bulk material undergoing various mechanical processes using a coupled DEM/CFD approach. Powder Technology, 355, 37-56.