RESEARCH AND APPLICATION OF NEW DUST CONTROL TECHNOLOGIES FOR BULK MATERIALS HANDLING PROCESSES

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ABSTRACT

Industries that handle and process "dusty" bulk materials are facing increasingly difficult challenges to ensure sustainable operation and development. Most existing dust control measures treat only the "symptoms" of dust generation and do not deal with the root cause/s of the problem. Many of these methods also are relatively inefficient in terms of controlling dust emissions. This paper summarises initially the various existing options available for dust control and some of their features, advantages and disadvantages. It then describes some of the new technologies that are being researched, developed and employed to minimise dust emissions by addressing dustability or dustiness and the dust generation mechanisms found in industry. Some recent research results and case studies are presented to demonstrate some interesting findings obtained from this work. With improved understanding and modelling of dust generation mechanisms and also bulk material dustiness, it is possible to achieve a step-change improvement in the design, troubleshooting and application of more efficient dust control technologies.

INTRODUCTION

Fugitive dust emissions from the mining, handling and/or processing of bulk materials are creating an increasing number of problems for industry, the community and government. For example: loss of material and export income; increasing workplace dust emissions; increasing direct costs to industry; deteriorating ambient air quality and human health; residential complaints. These problems are exacerbated as larger quantities of ore are mined, processed and/or handled, and especially as the products become finer. Some of the "traditional" ways to control fugitive dust emissions include: general ventilation (i.e. dilution of airborne dust concentration to acceptable levels); containment (e.g. enclosures with integral filtration); "push-pull" systems (using the "air-knife" or "air-curtain" concept); dust suppression veneer (surface) treatment (e.g. rail wagons, trucks, stockpiles); water spraying systems trying to suppress airborne dust particles (e.g. see Figure 1); dust agglomeration (via ionisation or ultrasonics); local exhaust ventilation (LEV), also known as dust extraction, with dust filtration; wind barriers or diffusers (e.g. trees, walls, mesh); vegetation (e.g. grass, shrubs) to help capture/trap airborne dust over large flat areas.

Most of these dust control measures really only treat the "symptoms" of dust generation and are considered as "protection" methods (i.e. they do not deal with the root causes of the problem). Also, some have been found to be relatively inefficient in terms of controlling fugitive dust emissions. For example: LEV requires suction flows, which can be relatively inefficient in capturing airborne dust, where the exhaust velocity reduces dramatically from the face of the hood (ACGIH, 1998); traditional water spraying systems, such as those shown in Figure 1, are inefficient in dealing with fine dust (due to the coarse droplets produced) and cannot seem to cope with associated air flows and external disturbances, such as cross winds; dust suppression veneers need to be re-applied whenever the treated product surface is broken or disturbed (e.g. after loading/unloading trucks or rail wagons).

The following areas have been identified to be some of the main causes or "offenders" of fugitive dust emissions: ROM bins; dump hoppers at truck/rail unloading stations; stockpile stacker/reclaimers; conveyor transfers; crushing stations; and haul roads in open cut mines where trucks continuously generate/agitate fine dust, which is then easily dispersed by cross-winds.

To achieve a step-change improvement in understanding and solving fugitive dust emission problems for industry, more fundamental research needs to be undertaken to address the application areas listed above. The following sections summarise some of the new technologies that are being researched and developed for this purpose. Some industrial case studies are included to demonstrate some particular features and results.

Figure 1: Examples of ROM Bin Water Spraying Systems

DUSTINESS

Problem quantification is an important early step in the design or troubleshooting of a dust control system. Two standards that can be used to quantify the dustiness of bulk materials are: AS4156.6 (2000), which was originally developed for coal; and EN15051-2 (2013), which was developed for a wider range of bulk materials. Figure 2 shows the two different rotating drum dustiness testers based on these standards and some materials being tested: dry sand in the AS4156.6 (2000) tester on the left and dry iron ore in the EN15051-2 (2013) tester on the right. Examination of these two standards has identified some key differences that can influence the accuracy and validity of the results from the two rotating drum tests (Wypych *et al.*, 2013). For example, the amount of material required in each tester is quite different (e.g. 1000 versus 35 mL) as can be seen in Figure 2. This will affect the amount of dust collected. Some of the other differences, such as test duration, rotational speed and extraction air flow, will also affect the amount of dust generated and hence, the dustiness or dustability of the material.

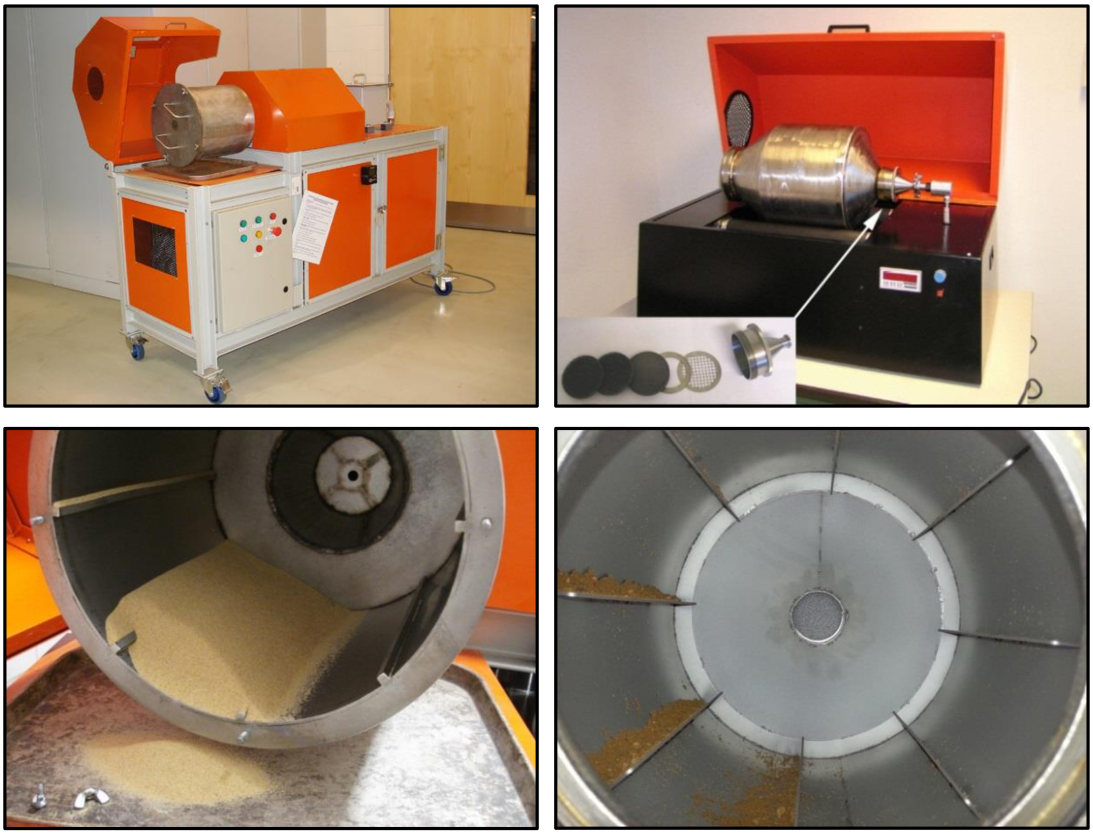

Figure 2: Rotating Drum Dustiness Testers: AS4156.6 (2000) (left); EN15051-2 (2013) (right)

There are also some fundamental differences in the overall aim or focus of each standard. AS4156.6 (2000) mainly deals with the dust/moisture relationship and how the Dust Extinction Moisture (DEM) is determined for a particular product. Equation (1) is used to determine the dust number (dustiness) at a particular moisture content. The dust numbers at different moisture contents are plotted on a log-linear graph as shown in Figure 3. AS4156.6 (2000) describes how an exponential trendline is fitted to the data and used to determine the DEM for the material. The DEM is defined as the moisture at which the Dust Number is 10.

$$\text{Dust Number} = (\text{Mass of Dust, grams}) \times 10^5 / (\text{Mass of Sample Placed in Drum, grams}) \quad (1)$$

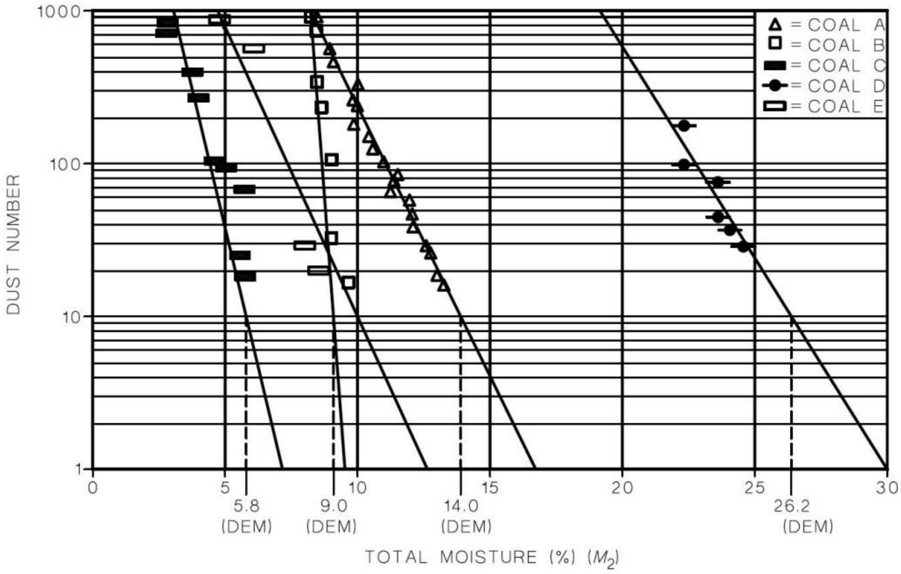

Figure 3: Dust/Moisture Curves for Australian Coal, showing DEM = 5.8 to 26.2% wb (AS4156.6, 2000)

Figure 3 shows how the DEM can vary significantly for coal, from 5.8 to 26.2% wb (wet basis), and also how the slope of the dust/moisture relationship can be quite steep or shallow, depending on coal type. Similar variations in dustiness have been observed for many other different types of bulk material. Such data and trends can have significant effects on dust control efficiency.

EN15051-2 (2013) focusses on measuring and classifying the dustiness or dustability of a particular powder sample for workplace emissions, based on the inhalable, thoracic and respirable dust mass fractions. If the Inhalable Dust Mass Fraction (IDMF) is found to be > 3000 mg/kg, then the dustiness of the powder sample is classified as “high”. Although not described in EN15051-2 (2013), it is possible to determine a dust/moisture relationship for a particular powder by simply repeating the test for different moisture contents. Equation (2) can then be used to calculate equivalence between the two standards.

$$\text{IDMF (EN15051-2, 2013)} = 10 \times \text{Dust Number (AS4156.6, 2000)} \quad (2)$$

Based on research conducted to date, some other issues have been identified as possible limitations and/or errors sources of the two current rotating drum tests. Some potentially significant issues are summarised below.

- The exponential dust/moisture curve stipulated by AS4156.6 (2000) does not necessarily occur for all bulk materials and can provide misleading results (Wypych *et al.*, 2015).
- At moistures approaching DEM, some adhesion of product is noticed on the inside of both rotating drums (Wypych *et al.*, 2013). Such adhesion is expected to have an appreciable effect on the results.

To investigate possible differences between the two standards, “side-by-side” experiments have also been performed and presented (Wypych *et al.*, 2013). The resulting difference in the DEM (viz. DEM = 5.2% wb based on AS4156.6 and 3.8% wb based on EN15051-2) indicates a significant difference in the moisture that would be required for dust control. For example, for an application requiring 5000 tph of coal, the difference in water required would be 70,000 litres per hour.

Some possible key improvements to dustiness testing are being investigated, such as:

- Collecting the entire dust sample from an AS4156.6 (2000) dustiness test and then determining its Particle Size Distribution (PSD), so that inhalable, thoracic and respirable dustiness mass fractions can be determined.
- Re-designing the dust chambers and transfer pipes/tubes to avoid dust deposition, which has been evident in some tests.
- Investigating possible “system” effects via experiment, DE (Discrete Element) simulation modelling of the particle flows and also coupled DE-CFD (Computational Fluid Dynamics) simulation modelling of the particle-air flows inside each rotating drum. For example, using poly pellets to maximise visibility for high-speed video, a snapshot of a typical experiment based on AS4156.6 (2000) is shown in Figure 4, which includes a DE simulation based on a relevant calibrated material model (Grima and Wypych, 2011). It can be seen from the DE simulation in Figure 4 that a certain layer of particles within the rotating sample has an absolute velocity quite close to zero. This could imply that a certain amount of “central” material may not be agitated and exposed sufficiently to the main “extraction” air flow inside the central part of the drum. This could affect the amount of dust released during a test. To explore these issues further, more experiments and DE simulations are being pursued on both testers (and using other types of bulk material, including iron ore and coal). Coupled DE-CFD simulations are also being pursued currently to investigate particle-air interactions directly.

Such on-going research is being pursued with the overall aim of developing a reliable and practical dustiness tester that is representative of the bulk material sample and contains minimal system effects or operator dependencies.

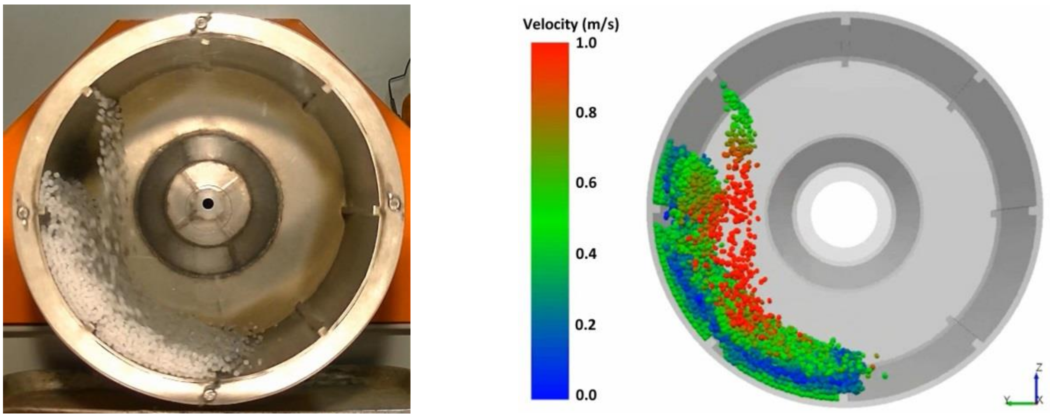

Figure 4: AS4156.6 (2000) Dustiness Test: Experiment (left); DE Simulation (right)

AIRBORNE DUST SUPPRESSION

For water spray or misting systems to be effective in controlling/suppressing airborne dust, the mist curtain efficiency and energy need to be matched to suit the product flow rate, the process-driven air flows and any external disturbances, such as cross-winds, moving equipment or obstructions. Other factors that need to be considered for this purpose include: dust PSD and concentration; water droplet size distribution (DSD); nozzle design; water quality; inertia and momentum of dust particles and air (including “gusts”); inertia and momentum of droplets; dynamic “balancing” of droplets with particle-air mixture; plant orientation.

Some examples of results obtained from research into mist curtain efficiency are shown in Figure 5. This work was undertaken to solve dust emission problems at a rotary rail car dumper, as shown in Figure 6 (left). The maximum velocity of dust-air flows was measured, and samples of dust also were collected and the PSD measured using a laser diffraction analyser. A high-energy micro-mist nozzle was then selected to “match” this application/dust, mainly in terms of air/dust energy and also the DSD. The resulting high-energy micro-mist curtain is shown in Figure 6 (right), which clearly displays successful results. Without the micro-mist curtain, the dust emissions shown in Figure 6 (left) return immediately – and it is not possible to stand alongside the handrail shown in Figure 6 (right). This more scientific and engineering approach in solving difficult dust problems in industry is being undertaken via a strategic R&D collaboration with EnviroMist Pty. Ltd. (e.g. conveyor transfers, crushing stations, ROM bins, rotary rail car dumpers and stacker/reclaimers).

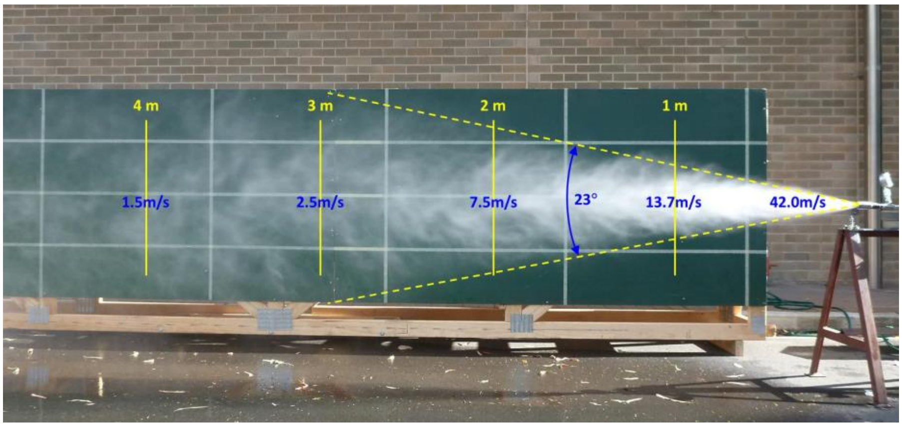

Figure 5: Characterisation and Modelling of new EnviroMist High-Energy Micro-Mist Nozzle

Figure 6: Rotary Car Dumper with excessive Dust Emissions (left) and efficient Dust Suppression (right)

DUST GENERATION MECHANISMS

Understanding and modelling dust generation mechanisms will assist greatly in tackling the root cause/s of fugitive dust emission problems. This also will help to optimise and minimise the size and cost of the “final” dust control system needed for a given product and application. The problem has been studied experimentally using free-falling streams of various bulk materials (Cooper and Wypych, 2001; Liu *et al.*, 2007), theoretically (Liu, 2003) and numerically (Wangchai *et al.*, 2013).

The total amount of air “generated” (that causes fugitive dust emissions) consists of: interstitial air entering the product discharging from the hopper outlet (due to expanding voidage inside the hopper); air being dragged by the material stream (referred to as induced air); entrained air (due to the expanding voidage of the free-falling stream of bulk material); displaced air (due to particles entering the container). Based on experience and research, entrained air has been found to be most dominant, even for relatively small drop heights. For example, Cooper and Wypych (2001) found that entrained air is proportional to drop height raised to a power of $n = 5/3$. It is interesting to note CEMA (2007) presents an equation for entrained (induced) air to assist in the design of dust control systems for conveyor transfers. This equation can be simplified to show that the drop height exponent, $n = 2/3$. This means that doubling drop height will result in a 60% increase in air entrainment (and corresponding control volume). However, based on the experimentally verified value of $n = 5/3$, a doubling of drop height will actually result in a 220% increase in air entrainment (not 60%). Hence, it appears that CEMA (2007) will significantly underestimate the effect of drop height on entrained air (and required control volume for effective dust control).

CONCLUSIONS

Fugitive dust emissions from the mining, handling and processing of bulk materials are creating an increasing number of problems for industry, the community and the government. Most of the existing dust control measures only treat the "symptoms" of dust generation and can be considered as "protection" technologies. New technologies are being researched and developed to achieve a step-change improvement in solving fugitive dust emission problems for industry, such as: quantification and modelling of the dustiness of bulk materials; new micro-mist airborne dust suppression systems that can be matched and optimised to suit different applications; modelling of air entrainment processes that contribute to significant dust emission problems.

Further work still needs to be done in the area of dust control, including: standardisation of dustiness testing and subsequent determination of dust extinction moisture; research and development of sustainable "total particle" dust suppression technology, where the ore is treated at the mine site before being loaded onto trains or trucks; research and development of new high-energy micro-mist technology that can tackle large-scale applications (e.g. ROM bins, stacker/reclaimers, truck/rail unloading stations, haul roads); development of coupled DE-CFD models to predict product, air and dust flows for design purposes.

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