Additives to Marra Mamba Iron Ore to Reduce Dust Emissions

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Abstract

Dust generated within iron ore processing plants are particles with diameters on the order of micrometres. Marra Mamba, a type of iron ore mined by BHP in the Pilbara region, has a greater tendency to form dust due to its higher percentage of fine particles. Dust inhalation, limited visibility and loss of product are examples of issues resulting from dust. BHP currently utilise water sprays to increase the iron ore moisture to the dust extinction moisture (DEM), the optimal moisture at which dust generation is negligible. Introducing additives to the spray water has the potential to reduce the DEM, such that less water is required in preventing dust and more iron ore can be railed to Port Hedland for export. Three additives were selected for testing to determine the optimal additive and dosage rate achieving the greatest reduction in DEM. Using the dust tumbler test, the natural DEM for Marra Mamba iron ore without additive was 8.9%. Additive B was established as the most effective additive, achieving a reduction in DEM to 7.9% at a dosage rate of 0.3 litres per tonne of dry iron ore. The reduction however was not found to be statistically significant, and it is recommended that additional data be obtained to confirm this.

1. Introduction

1.1 Overview

Iron ore from the Marra Mamba Iron Formation of the northwest Pilbara region (Klein and Gole 1981) is mined by BHP. Marra Mamba iron ore is known for its ochreous or yellow-brown colour due to a high goethite content, and possesses a higher friability (ability to crumble) compared to other iron ore types (Lascelles 2000). This generates a greater proportion of fines <125 μm in size compared to other ore types (Okazaki and Higuchi 2005), resulting in a greater tendency to form dust.

Dust particles, those with diameters <150 μm (Standards Australia 2013), are created during iron ore processing and remain suspended in the air. Fugitive dust at the PM10 fraction (<10 μm in diameter) can be responsible for health issues (Topić and Žitnik 2012). Occupational inhalation of high iron oxide dust concentrations over the long term can lead to benign pneumoconiosis, termed siderosis (BHP Iron Ore, 2007). The crystalline silica present is believed to be carcinogenic towards humans (IARC 1997). Dust on site is abrasive to equipment and reduces visibility (Topić and Žitnik 2012). Dust also represents producer losses, so reducing emissions would offer economic benefits in addition to health and safety benefits.

Water is introduced to iron ore through sprays to inhibit dust generation, as the surface tension of water increases the cohesive forces between particles, thus preventing airborne dust (Topić and Žitnik 2012). An optimal moisture level exists at which a negligible level of dust is produced, known as the Dust Extinction Moisture (DEM). The DEM is defined by AS 4156.6-2000 as the moisture level on a mass basis that yields a dust number of 10 on a dust/moisture curve (Standards Australia 2013). The dust number represents the mass percentage of dust produced based on the original amount of material, multiplied by 100,000. A dust number of 10 means the dust produced is only 0.01% by mass of the total amount present.

Increasing the moisture content of the ore towards the DEM within processing plants requires significant amounts of water which comes at both environmental and economic cost. Dust prevention additives added to the spray water may reduce the DEM, resulting in decreased water consumption, and the lower moisture level increases the mass of iron ore that can be railed towards Port Hedland.

1.2 Literature Review

The introduction of water to iron ore forms liquid bridges between particles where the surface tension of the bridge results in cohesive forces (Nyembwe et al. 2016). These forces cause the agglomeration of fine particles, reducing the probability of them lifting up into the air as dust. The mass of water adhered to a particle can itself also contribute to preventing lift-off.

Previous dust prevention studies have largely focussed on coal, where dust is a significant health and safety issue. Wettability refers to the ability for liquid to contact a material, however water sprays are not able to wet coal particles due to coal's hydrophobicity (Mohal 1988). Surfactants or wetting agents decrease the surface tension of water to increase wettability (Copeland and Kawatra 2005), and it was found that combining water sprays with surfactants improved the wettability of coal to significantly reduce dust generation (Tien and Kim 1997). By decreasing surface tension, surfactants also decrease the cohesive forces of the liquid bridges. It may be the case that the reduced cohesive forces are still sufficient for agglomeration.

Based on the promising results of surfactants with coal, it was considered that surfactants could yield similar benefits for iron ore (Copeland and Kawatra 2005). A dust test was devised which involved dropping ore through a tower, passing a countercurrent air stream to collect fines and measuring the PM10 concentration. Using ore samples that had reached equilibrium with a surfactant after a 2 hour cure time, Copeland and Kawatra concluded across multiple studies that surfactants did not show any improvements in dust prevention (Copeland et al. 2008, Copeland and Kawatra 2011). A possible issue with the experimental procedure used was that the samples were tested at a very low moisture level, obscuring the surfactant's ability to reduce dust as the surfactant could only enhance the effect of a minimal amount of water.

Copeland and Kawatra also considered sodium metasilicate as well as calcium and magnesium chloride, which are classified as hygroscopic reagents (Copeland et al. 2008, Copeland and Kawatra 2011). Commonly used in controlling dust on unpaved roads, hygroscopic chemicals function through absorbing moisture from the air and reducing evaporation (Kirchner and Gall 1991). For the same tower drop test, the hygroscopic reagents were significantly superior to the surfactants, but this may be partly due to the higher concentrations tested compared to the surfactant concentrations.

1.3 Objective

Having selected three additives, the main objective was to determine the optimal additive and corresponding dosage rate needed to achieve the greatest reduction of DEM for Marra Mamba iron ore.

2. Process

Overall, 10 different tests for DEM were conducted. Three different dosage rates per additive were tested for their effect on DEM, at 0.5, 1 and 1.5 times a selected dosage rate. Also tested was Marra Mamba iron ore without additives to establish a baseline DEM value for comparison. Each of the additive vendors provided a range of recommended dosage rates. For the amount of iron ore that needs to be dosed within a processing plant, the additive costs can become excessive with too large a dosage rate. Consequently, the lower bound of the suggested ranges were selected for testing, listed in Table 1.

Additive	Dosage Rate	0.5 × Dosage Rate	1.5 × Dosage Rate
Additive A	12 g per 1 tonne	6 g per 1 tonne	18 g per 1 tonne
Additive B	0.2 L per 1 tonne	0.1 L per 1 tonne	0.3 L per 1 tonne
Additive C	2.5 mL per m^2	1.25 mL per m^2	3.75 mL per m^2

Table 1 Tested additive dosage rates (based on mass of dry iron ore)

Dust tumbler tests were used to determine DEM for the different dosage cases, conducted by Jenike & Johanson (J&J) in accordance with AS 4156.6-2000.

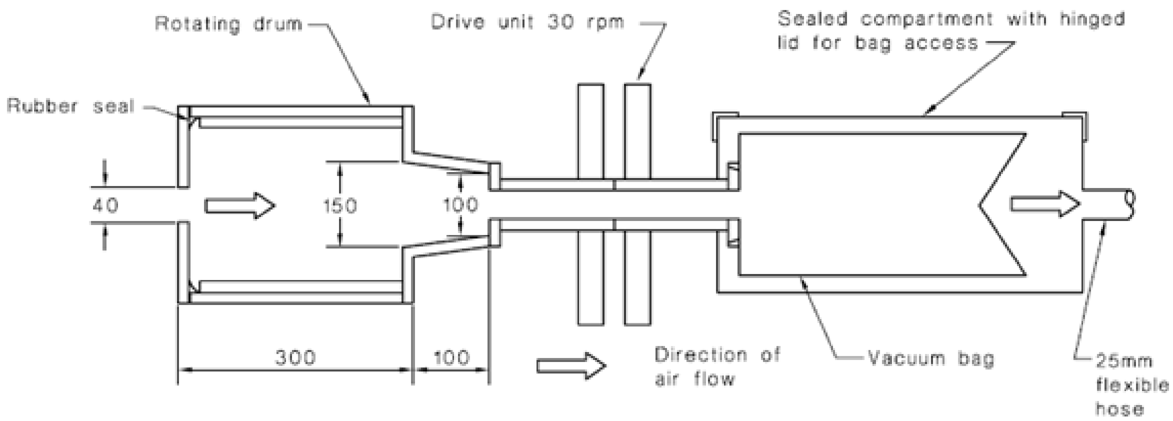

Figure 1 Tumbler test rig schematic (Standards Australia 2013)

Figure 1 is a schematic illustration of the tumbler test rig (presented in AS 4156.6-2000) used to measure dust number. To determine DEM, a plot of dust numbers versus moisture content is required. The dust number is given by (Standards Australia 2013):

$$dust\ number = \frac{(M_b - M_a)}{M_s} \times 100000$$

M_b = Mass of filter bag and dust
M_a = Mass of filter bag
M_s = Mass of sample placed in drum

Exponential regression analysis is used to fit an equation to the dust number/moisture data. The DEM is the moisture corresponding to a dust number of 10 on the regression line (Standards Australia 2013). To find a single dust number and the corresponding moisture, a 3 kg sample of iron ore is dosed with additive and water to reach a predetermined moisture. 0.5 kg of the 3 kg is placed into an oven to confirm the moisture level while the other 2.5 kg of ore is placed into a drum that is rotated at 29 rpm. While rotating, 175 L/min of air is drawn through the drum to carry dust particles into filter bag. After 10 minutes of rotation the drum stops and the filter bag with collected dust is carefully removed to be weighed.

3. Results and Discussion

The results are presented in Table 2 for all the 10 dosage cases. The DEM for Marra Mamba iron ore without additive was found to be 8.9%. It was observed that for each additive, the higher the dosage rate, the larger the decrease in DEM. Compared to the baseline, additives A and C were only able to achieve absolute moisture reductions of 0.6% and 0.3% respectively at their highest dosage rates. The greatest improvement in DEM from the baseline was Additive B at a dosage rate of 0.3 litres per dry tonne, with an absolute 1% reduction to an improved DEM of 7.9%. From these results, Additive B was chosen as the optimal dust prevention additive with a corresponding optimal dosage rate of 0.3 L/t. The dust/moisture curves for Marra Mamba without additive and with Additive B at 0.3 L/t are displayed in Figure 2.

Additive	Dosage Rate	DEM (%)	Lower Bound (%)	Upper Bound (%)
None (Baseline)	None	8.9	8.0	10.1
Additive A	6 g/t	9.2	8.5	9.9
Additive A	12 g/t	9.1	8.6	9.8
Additive A	18 g/t	8.3	7.9	9.0
Additive B	0.1 L/t	8.9	8.0	9.8
Additive B	0.2 L/t	8.7	7.8	9.9
Additive B	0.3 L/t	7.9	7.2	9.0
Additive C	1.25 mL/m^2	9.0	8.2	10.1
Additive C	2.5 mL/m^2	8.8	8.6	9.1
Additive C	3.75 mL/m^2	8.6	8.2	9.3

Table 2 Effect of different additives and dosage rates on DEM (including 95% inversion intervals for DEM)

Regular confidence intervals cannot be generated for the DEM as moisture is the explanatory variable. Fitting a model with dust number as the explanatory and moisture as the response would not be appropriate because the regression model assumptions are not satisfied (Greenwell and Schubert Kabban 2014). Instead, 95% inversion intervals were created using the `investr` package in `R`, which are appropriate for inferring the unknown value of the moisture corresponding to a dust number of 10 (Greenwell and Schubert Kabban 2014). Although a reduction in DEM from 8.9% to 7.9% was observed, the intervals for the two moistures in Table 2 and Figure 2 overlap, (8.0%, 10.1%) for the no additive scenario and (7.2%, 9.0%) for Additive B at 0.3 L/t. This suggests that the reduction is not statistically significant. Due to the extensive scope of testing and limitations on available material/funds, only 6 data points were obtained in each case to generate the regression line. This contributes to the large ±1% deviations in DEM. It is recommended that additional data be obtained to confirm whether the reduction is significant.

As discussed above, the dosage rates selected for testing were based off the lower bound of ranges provided by vendors. For Additive A and B, the maximum dosage rates tested were still less than the upper bound suggested by vendors. Testing the upper bounds may have yielded improved results for any of the additives and a different outcome for the optimal additive rate and dosage rate. This however was assumed to come at significant financial cost if the additives were to be implemented on site at these elevated dosage rates.

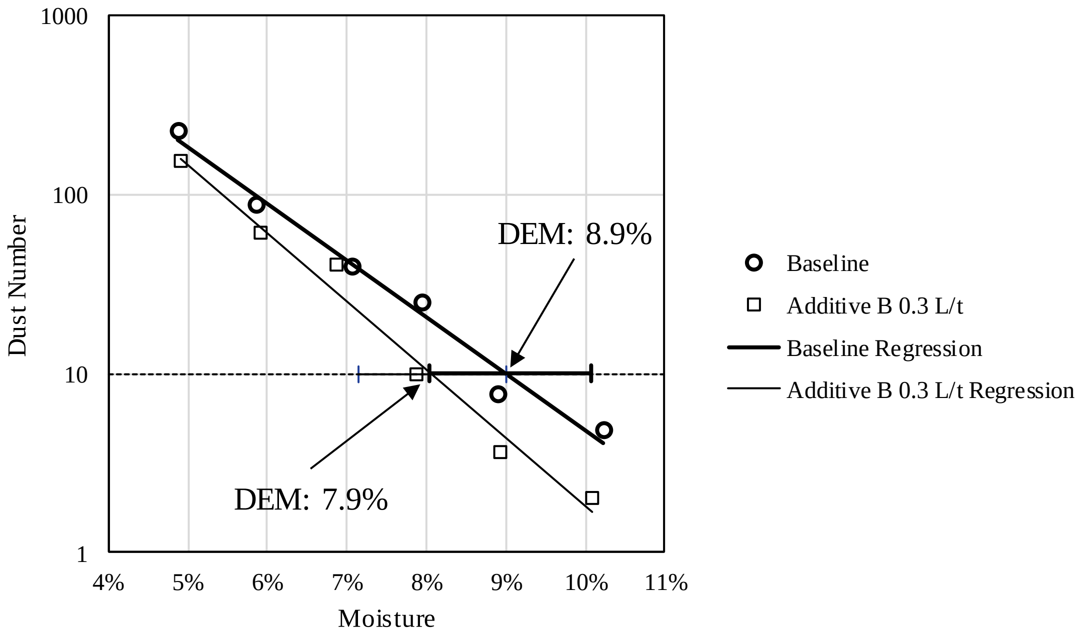

Figure 2 Dust/moisture curves for baseline and optimal scenario (including 95% inversion intervals)

4. Conclusions and Future Work

Three dust prevention additives were assessed on their ability to reduce the DEM of Marra Mamba iron ore, ensuring minimal water is consumed in meeting the required moisture level to prevent dust. Through use of the dust tumbler test it was shown that Marra Mamba's natural DEM without additive was 8.9%. Additive B was determined as the optimal additive, reducing DEM to 7.9% at an optimal 0.3 litres per dry tonne dosage rate. 95% inversion intervals were created for the DEM values, where the overlapping of (8.0%, 10.1%) and (7.2%, 9.0%) intervals for the no additive and Additive B scenarios respectively, suggest the reduction was not statistically significant. A recommendation is to increase the number of points tested on the dust/moisture curves to confirm whether the reduction is significant.

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