Dust Emissions from Coal Wagons

Reducing Emissions from the Surface of Coal

Fig. 1: Photo of typical open rail wagons.

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Due to the increase in Australian coal's demand and potential increase in dust emission, the Australian coal industry is committed to minimize the impact of dust emission from the bulk solids handling system. Research work carried out to assess the performance of experimental methods of reducing dust emission from the surface of coal in rail wagons show that a significant reduction in emissions is possible.

To meet the demand for Australia's coal, an efficient, economic transport system is a key element in the viability of coal mining and export. As the production of coal increases, rail transport is expanding.

The majority of coal is carried to the ports by rail. As the Australian coal industry is committed to operating in an environmentally responsible manner, and to continuously improve its environmental performance in the handling and transport of coal, the industry is committed to minimize the impact of dust emission from the bulk solids handling system.

This article presents experimental procedures and details of a purpose designed wind tunnel to assess the performance of experimental methods of reducing dust emission from the surface of coal in rail wagons. This work has been conducted in the laboratories of Tunra Bulk Solids Research Associates at the University of Newcastle in New South Wales, Australia.

Wind tunnel testing was conducted to evaluate the amount of fine particles removed from the surface of open rail wagons due to wind created by train speed and ambient winds. Due to the long travel distances surface moisture evaporates at an early stage of the rail journey and leads to significant dust emission. Different dust suppression chemical treatments have been tested for application to the coal surface and the results are presented. It can be clearly seen that a significant reduction in dust emissions is possible with the correct surface application of a chemical veneer treatment.

1 Introduction

Coal mining is a major contributor to the Australian economy, and for that reason an efficient and economically viable transport system is a key element in the coal mining industry.

The old mines are located close to the coast where domestic transport is well established. However, as new remote deposits are being discovered and open as production volume are increasing. As the production chain speeds up due to the coal's demand, the simultaneously developed and expanded rail transport infrastructure is the most important element in this change.

The majority of coal is carried to its destination by rail and in the major producing states; coal is the single most valuable rail freight.

Trains transporting coal are among the longest in the world, with as many as 6 locomotives and 148 wagons amounting to a length of more than 2 kilometres. A train of that size can carry about 8500 tonnes of coal.

The main rail companies operating in Australia are QR National and Pacific National who together service the States of Queensland, New South Wales and South Australia.

The export coal industry in Australia is serviced by nine coal loading terminals located in Queensland and New South Wales (see Tables 1 and 2).

Table 1: New South Wales's port capacity and export loadings 2007 and 2008; in million tonnes.

Ports	Annual Capacity 2007/2008	Export Loading 2006/2007	Export Loading 2007/2008
Newcastle	102	81	89
Port Kembla	16	12	13
Total for NSW	**118**	**93**	**102**

Table 2: Queensland's port capacity and export loadings 2007 and 2008; in million tonnes.

Ports	Annual Capacity 2007/2008	Export Loading 2006/2007	Export Loading 2007/2008
Abbot Point	21	11	13
Brisbane	6	4	6
Dalymple Bay	68	50	44
Gladstone	75	52	54
Hay Point	44	36	37
Total for QLD	**214**	**153**	**154**

Fig. 2: The wind tunnel apparatus.

As a result of expansion work in recent years, the terminals currently have a total handling capacity in excess of 330 million tonnes of coal a year with further expansion planned or in progress. Table 1 shows ports capacities and coal export loading for 2007/2008 in million tonnes for the state of New South Wales.

Table 2 shows ports capacities and coal export loading for 2007/2008 in million tonnes for the state of Queensland.

Due to the increase in Australian coal's demand and potential increase in dust emission, the Australian coal industry is committed to operating in an environmentally responsible manner, and for that reason continuously finding new ways to minimize fugitive dust and to ensure that there is no subsequent environmental adverse effect on adjacent residential areas. Considerable attention is now given to research to help improve management and operational practices to minimise environmental issues resulting from handling and transport operations

For this reason over previous years there has been a serious research conducted in order to find ways to minimise the amount of fine particles being removed from an open stockpile due to prevailing winds. In order to achieve this, test work was performed to determine the amount of material emitted by varying the moisture content. By doing so the aim was to determine the relationship between the dust emissions or fine dust particles being produced with the change in moisture for each material type.

In the mining of coal, the industry is committed to minimize its impact on all parts of the environment, whether visual landform, air and water quality, noise levels and soil conditions

The Standards Australia Committee MN/1 in 2000 prepared a standardized testing procedure for coal and coke which was based on the Rio Tinto Research and Technology Development Tumbler Dust Test as an improved version for the already existing ASTM D 441 procedure.

The main objective of this Australian Standard was to provide a procedure which would allow determination of the dustiness of coal with respect to moisture content and determination of the dust extinction moisture level (DEM). This Standard is highly utilised due to the overwhelming demand for Australia's coal, iron ore and other minerals. The DEM procedure has been utilised for these materials to provide important data in understanding means to minimise dust emission.

To ensure that unwanted dust emissions are minimized from open stockpiles and rail wagons, the wind tunnel apparatus was designed and built by Tunra Bulk Solids (TBS), and in association with Introspec Consulting, a procedure was developed and implemented to conduct wind tunnel research. This program/procedure is becoming highly recognized in Australia for wind tunnel testing of dust emission from bulk materials.

2 Wind Tunnel Test Apparatus

The wind tunnel apparatus shown in Fig. 2 was specifically designed and built to simulate the flow of wind across the material surface. The apparatus is a suction unit as opposed to a more conventional blowing unit. Air is drawn through the wind tunnel unit causes a shearing effect between the airstream and the material sample surface, creating surface drag forces picking up small and loose material particles. The main components of the wind tunnel rig are:

a) the wind tunnel unit,
b) the fan intake vibration isolator,
c) the radial fan unit,
d) the fan outlet duct,
e) the test sample tray holder, and
f) the triple VF drive and timer.

The wind tunnel unit was designed to achieve a consistent cross sectional flow over the surface of the test sample. A reasonable length working chamber with small wall roughness coefficient was chosen in the design stage to create a uniform laminar boundary layer along the wind tunnel base and in particular across the test sample surface. Therefore to build the wind tunnel unit, Perspex was chosen as the wall material which also has the advantage for visualizing the test work.

The wind tunnel unit consists of two major chambers:

- Working Chamber
- Contraction Chamber.

The working chamber has cross sectional dimensions of 550 mm × 650 mm and a length of 1200 mm and its main purpose is to create the smooth air flow before it reaches the tested sample. Inside the working chamber a tray holder is positioned to hold two test sample trays at an angle of repose.

The air drawn through the working chamber will, prior to reaching the test samples, achieve laminar boundary layer conditions. The flow continues along the chamber base towards the sample and across the sample surface with increasing pick-up velocity.

As mentioned earlier the shearing between the air-stream and the sample surface will create surface drag forces picking-up loose participles, creating dust emission which with time will significantly increase.

The main purpose of the contraction chamber is to join the working chamber to the radial fan intake. The contraction chamber is 1200 mm long, with all four sides tapered to a cross section of 400 mm × 400 mm at the fan intake. It was designed to these dimensions to avoid any vortex and back pressure being created in the contraction chamber which will affect the working chamber flow.

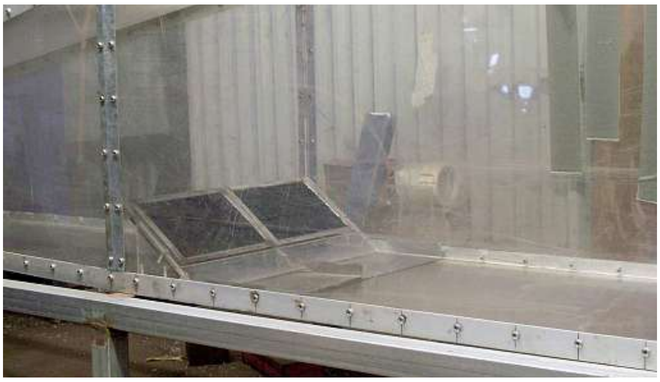

Fig. 3: The wind tunnel test tray holder and trays at 37°.

3 Sample Preparation and Test Procedure

The material sample used for wind tunnel testing is screened to remove any product greater than 6.3 mm to represent the size which would be most vulnerable to dust lift-off and furthermore to increase consistency in the results from relatively small sample trays. The sample screening procedure is adopted from Australian Standard AS-4156.6-2000.

To simulate the typical stockpile moisture level an allowance is made in the pre-test sample moisture level for loss of moisture due to evaporation which is most likely to occur during handling operations between arrival at the port and construction of the completed stockpile.

It is assumed that a small percentage of moisture will be lost on arrival at the stockpile. Therefore, to simulate the operational situation, the moisture content level used in the wind tunnel test sample is set to be 75 per cent of the DEM value previously determined.

When a stockpile surface is treated with dust suppressant agent the fine particles are agglomerated together and this bonding creates a protective layer or crust. The crust formed is generally 5 to 10 mm thick and is usually strong enough to resist wind impact. Each sample is placed in an oven for a period of 30 minutes at 35 °C to simulate the additional loss of moisture due to evaporation from the surface of the completed stockpile after suppressant agent has been applied.

Each material type has a different dust lift-off wind speed (i.e. pick-up velocity) and for that reason it is extremely important to conduct pick-up velocity tests to determine which wind speed occurs for each material. Therefore consequently the wind pick-up velocity test for each material needs to be determined.

When a sample is placed in the tunnel initially only air is conveyed across the surface, however, with increasing air flow particles start to migrate along the surface (saltation), followed by smaller particles becoming air-borne (minor dust pick-up) and

Table 3: Dust lift-off for coal sample type A.

Moisture content [%]	Treatment	Train speed [m/s]	Material loss: dust lift off [g]	Material loss: dust lift off [g/m²]
6.4	Nil	16.7	192	5703
6.4	water	16.7	18	548
6.4	DS-1 @ 4 %	16.7	7	136
6.4	DS-1 @ 6 %	16.7	0	0

then by larger particles (major dust pick-up) as the air flow speed is increased.

This preliminary test gives the dust pick-up velocity value for each material. By determining dust lift-off velocity values for material it helps establishing most appropriate stockpile treatment and the air speed at which samples should be tested.

Although the wind tunnel unit can create air flow velocities up to 30 m/s, the test wind speed and the duration of the tests, normally 8 hours, are selected to simulate likely extreme weather conditions at the location. Depending on the test simulation requirements a number of other test variables can be adjusted to simulate the operational situation.

4 Chemical Surface Veneer Treatment

The wind tunnel has been previously used to evaluate the use of veneer chemicals to reduce the amount of airborne dust from coal stockpiles and coal transported in rail wagons.

Recent research into the use of veneer treatment, involves the application of chemical in a water solution to the surface of the train wagons which is to forming a surface crust on the coal. Veneer treatment, not only effective on the wagon coal surface, but also minimises loss of moisture from the whole sample through the action of the surface crust.

Although the application of water is considered to be a cost effective means of controlling dust emission, research has shown that chemical veneer treatment can be used to improve the effectiveness of water.

The following observations have been made following coal stockpile surface veneer treatment test programs:

- Veneer treatment requires a single application, until the surface is disturbed during reclaiming, compared with water only, which requires repeat application at regular intervals due to evaporation and surface drying.
- Veneer treatment, compared with water only, demonstrated a superior ability to reduce the amount of dust lift-off occurring from the stockpile coal surface when exposed to a wind speed of 10 metres per second (36 kilometres per hour).
- In some situations the rate of dust lift-off with veneer treatment was measured at less than half the lift-off rate without veneer treatment.

The test programs demonstrated that the use of veneer treatment should only be necessary during those periods of the year that are subject to a combination of high temperature and high wind speed. The following has also been noted:

- Surface spray system water usage could be reduced following the application of veneer treatment.
- The use of chemicals for veneer treatment could be cost effective.

Test programs have also been conducted to demonstrate a high level of effectiveness of chemical veneer treatment on the surface of coal transported in open rail wagons.

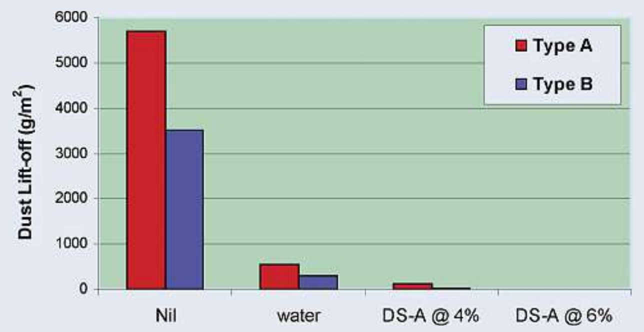

Fig. 4: Graphical results for different types of veneering treatment.

5 Wind Tunnel Test Procedure

The wind tunnel test program involved two typical coal samples from two different coal mines, and in order to assess dust-lift off from the two coal types samples a material sample is placed in a wind tunnel of square cross-section. The material sample is prepared in a tray positioned at the angle of repose in order to simulate actual conditions experienced in a train wagon. Each of the samples was prepared in trays at moisture content which is 75 per cent of the dust extinction moisture level (DEM). This dust emission moisture level was determine for the each coal sample prior to the wind tunnel tests. The coal sample Type A has a DEM level very close to the coal sample Type B which is 8.5 per cent and 8.9 per cent respectively.

The test program involves four different sample trays tested in the wind tunnel at a velocity of 16.7 m/s (60 km/h) and for a duration of 8 hours which is to replicate typical travel speed and time. The total dust lift off is derived from the actual loss in sample mass and the difference in measured moisture contents before and after the test work. Three different treatment options at an application rate of 0.5 l/m^2 were trialled in the wind tunnel experiment, being water and two different solutions of water and dust suppressant agent type 1 (DS-1) mixed at 4 and 6 per cent respectively.

For comparison, one test was also undertaken without any surface treatment. The tray holder and tray containing samples is placed in the working chamber for the duration of the test. The two test trays 225 × 150 × 25 mm deep are placed in the perspex tray holder at an angle of 37 degrees positioned in the wind tunnel. This simulates the typical coal's angle of repose shown in Fig. 3.

After completion of the tests, the sample trays were carefully removed from the wind tunnel chamber and taken to laboratory to be weighed and dust emission determined for each individual magnetite sample. The total dust lift-off was derived from the actual loss in sample mass and the difference in measured moisture contents before and after the test work.

Table 4: Dust lift-off for coal sample type B.

Moisture content [%]	Treatment	Train speed [m/s]	Material loss: dust lift off [g]	Material loss: dust lift off [g/m^2]
6.4	Nil	16.7	118	3511
6.4	water	16.7	11	311
6.4	DS-1 @ 4 %	16.7	1.2	36
6.4	DS-1 @ 6 %	16.7	0	0

6 Wind Tunnel Test Results

The results from the wind tunnel tests for the coal sample type A are given in Table 3, the results from the wind tunnel tests for the coal sample type B are given in Table 4.

From the test results shown in Tables 3 and 4 it is evidenced that the coal samples veneered with the dust suppressant agent type 1 (DS-1) have the ability to significantly control fugitive coal's dust.

This is largely achieved due to the dust suppressant agent type 1 (DS-1) and its ability to produce a stable surface crust created on the top of the wagon coal surface which acted like a wind shield deflector.

The dust-lift for all treated samples, including those treated with water, was small over an 8 hour period, unlike the sample without any treatment. The dust suppressant agent type 1 (DS-1) at 6 per cent has shown its effectiveness in retaining the dust lift-off to a satisfactory zero level, what can be seen in Tables 3 and 4 for both coal types, unlike the 4 per cent which showed slightly better results for the coal sample of type B than for the coal sample of type A.

7 Conclusion

The experimental procedures and apparatus described in this article have been used to determine the relationship between moisture content and dustiness, and the dust extinction moisture level, for coal, iron ore and other bulk materials. This information, produced in the TBS laboratories, has been used in research by Introspec Consulting to develop dust emission reduction programs for port terminals, power stations and rail transport systems.

As can be seen from Tables 3 and 4 and the graphical results in Fig. 4, the dust lift-off or dust emission in grams or grams per square metre for the both coal samples was lower for the samples that were treated with the dust suppressant agent type 1 (DS-1). Zero dust emission was achieved at 6 per cent dosage ratio. Slightly greater dust emission was observed for the sample that was treated dust suppressant agent type 1 (DS-1) at 4 per cent.

Surface treatment with water was not as effective as treatment with dust suppressant agent type 1 (DS-1). The coal samples that were not treated had high level dust loss during the test. ■

References

[1] Planner, J.H.: *Improved Management of Dust Lift-off from Coal Surfaces during Stockpiling and Rail Transport*. Keynote Paper 8th Int. Conf. on Bulk Materials Storage Handling and Transportation, Wollongong, Australia 2004.

[2] Planner, J.H.: *Implementation of new methods of dust management from mine to port*. IIR Conference , Mackay, Australia 2005.

[3] Planner, J.G.: *Management of Dust Emission from Coal Terminals*. IIR Bulk Materials Handling Conference, Brisbane, Australia 2006.

[4] Planner, J.H.: *Regional Ports, the Environment and Community Relations*. Regional Ports in Focus 2007, Mackay, Australia 2007.

[5] Planner, J.H.: *Dust Management in the Mine to Ship Coal Chain starts at the Mine.* IIR Conference, Brisbane, Australia 2007.

[6] Planner, J.H.: *Management of Bulk Solids Dustiness Characteristics to Minimise Dust Impact on Residential Communities*. 9th Int. Conf. on Bulk Materials Handling, Newcastle, Australia 2007.

[7] Djukic, M.; Planner, J.H.: *Determination of the Dustiness Characteristics of Bulk Solids Through the Use of Experimental Procedures and Test Apparatus*. 2nd BulkSolids Europe Conference, Prague, Czech Republic 2008.

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