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DELIVERING ONE OF AUSTRALIA'S BIGGEST UNDERGROUND DOWNHILL CONVEYOR SYSTEMS

Applying simulation methods to improve dust control outcomes

The exposure of workers to dust continues to be a major issue in Australia, highlighted by the re-emergence of coal workers pneumoconiosis (CWP) in Australian coal mines and increasing rates of silicosis. Jon Roberts, Peter Wypych, Vitold Ronda outline the results of two systems that were trialled in an underground coal mine to reduce dust generated by previously identified sources.

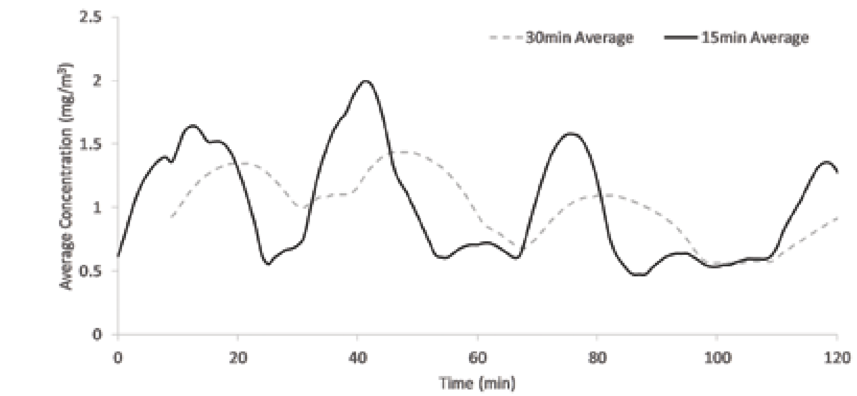

Figure 1: Dust concentrations showing peak measurements coinciding with roof support movements.

THE AUSTRALIAN COAL INDUSTRIES research program (ACARP) has recognised the issues that dust exposure has on workers in the bulk handling industry. It has funded the University of Wollongong and EnviroMist to research practices related to dust control system design, implementation, and validation (Project C26065).

Two systems were trialled in an underground coal mine to reduce dust generated by previously identified sources. Firstly, dust generated by the lower, advance, set roof support sequence, and secondly dust generated by the shearer when cutting the longwall face. High-energy micro-mist nozzles manufactured by EnviroMist were used for this project.

Real time dust monitoring was able to identify dust generated due to the movement of roof supports as being a major contributor to dust levels in the primary walkway. Figure 1 shows dust concentration measured over a two-hour period for which there are four distinct peak concentrations that correspond with the movement of roof supports upstream of the dust monitor. It should be noted that the 15-minute average dust concentrations measured exceeded the recommended occupational exposure limit (OEL) of 1.5 milligrams per cubic metre, this is only a short-term exposure, however, best practice would suggest that keeping dust concentrations below the OEL at all times should be the objective.

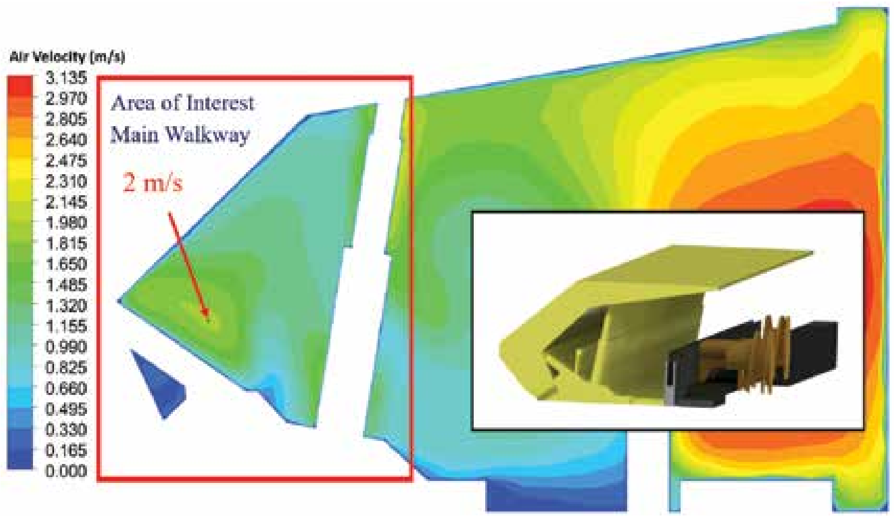

Figure 2: Cross section of longwall showing contours of air velocity.

Numerical modelling and application

Having identified the source of the dust the next step was to analyse the conditions in the area so that an appropriately designed dust suppression system could be implemented. Computational Fluid Dynamics (CFD) was used to analyse the ventilation flow on the longwall and in particular between the roof supports on the walkway. This allowed for peak air velocities to be predicted so that sprays could be selected such that they had sufficient energy to create a mist curtain across the walkway without deflecting excessively. Figure 2 shows the airflow predicted by CFD in the area of interest, a max velocity of two metres per second was predicted and as such the nozzles selected needed to be able to withstand this air velocity.

Based on the area to be covered and the air velocity predicted, a standard spray block consisting of five nozzles was deemed suitable, the nozzle size and operating pressure was calculated using the relationships presented in The Dynamics of Dust Suppression Sprays under Cross-Flow Conditions. The ability to relatively quickly estimate air velocities around complex geometries using CFD greatly enhances the design process especially when data is available to predict the coverage a spray will provide at

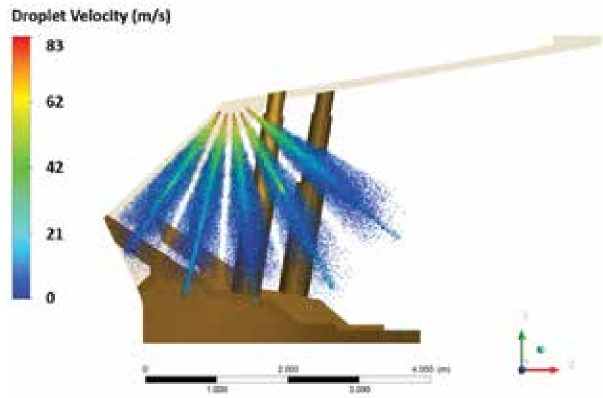

Figure 3: Results of CFD modelling of spray dispersion in proposed position.

different air velocities. Full coverage was required to ensure all dust escaping during the operation would flow through the mist curtain, Figure 3 shows the spray positioning as simulated using CFD; the sprays were incorporated into the simulation to predict the mist coverage based on the predicted airflow, this position provided full coverage of the walkway and directs dust and mist into the floor as much as possible. Due to the relatively low air velocity only minor deflection of the mist occurs and as such the nozzle size and pressure was selected based on droplet size and water usage, this allowed for selection of a nozzle producing the optimum droplet size for the lowest water consumption; in this case a high-energy micro-mist nozzle operated at a pressure of 100 bar corresponding to a flow rate of two litres per minute and a mean droplet size of approx. 35 µm was selected.

The system was designed as a trial across a section of the longwall with spray blocks installed on a series of roof supports (supports #5-10) which would operate whenever the adjacent upstream support would move. During the underground trials an unloader valve was used to adjust the pressure so that the influence of pressure on the performance of the system could also be investigated. The system was supplied with water at 16, 60, and 100 bar and the concentration of dust on the #11 support was measured for each, as well as with the system turned off completely. The dust monitor was placed on the #11 support so that it would not get significantly wet from the sprays on the #10 support, however, this did mean that the dust generated by the #10 support was being recorded. As well as this dust, because the system was only installed on supports #5-10, the dust generated by supports #1-3 were also being recorded by the monitor.

Figure 4 shows the dust concentrations measured per minute with each configuration of the dust suppression system operating. Again, it needs to be noted that the spray system is only operating on supports #5-10 and thus this data includes all dust generated upstream of the monitor from supports #1, #2, #3 and #10, as well as dust generated by the stage loader, crusher and any other operations upstream of the monitor. Based on this, it is impressive that the system was able to remove almost 50 per cent of dust passing through the walkway when operating at full pressure. The benefits of running the system at full

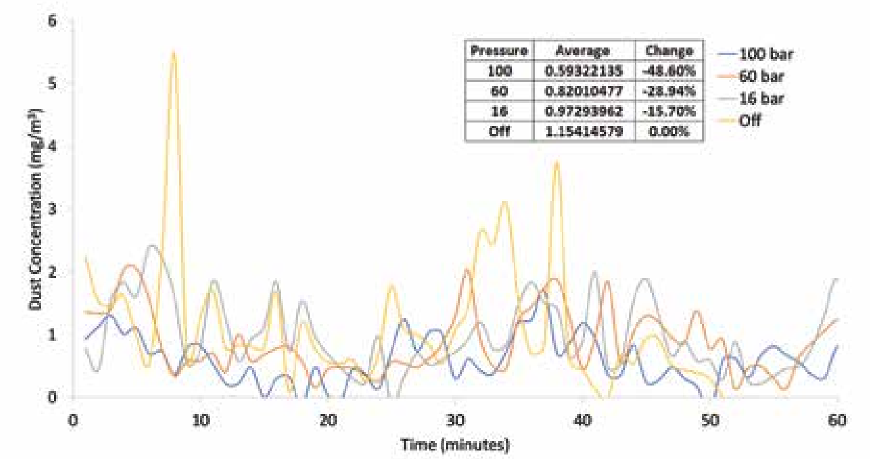

Figure 4: Dust concentrations measured during underground trials of roof support sprays.

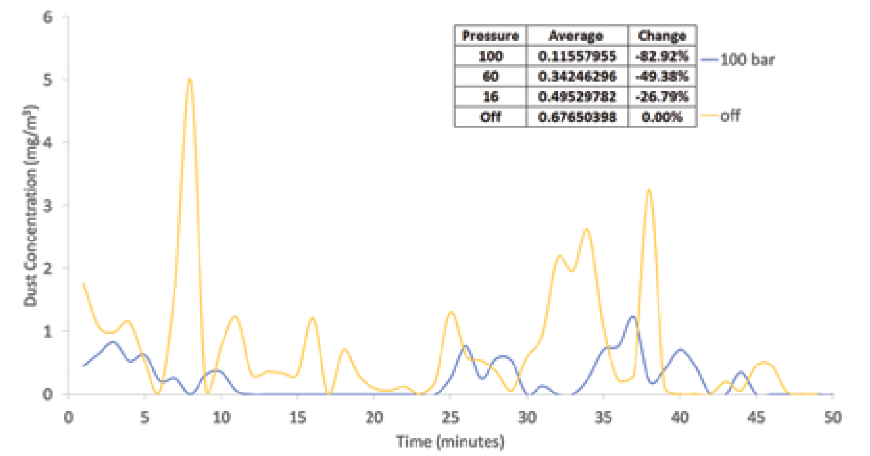

Figure 5: Dust concentration measured during trial of roof support walkway sprays with the average upstream concentration removed.

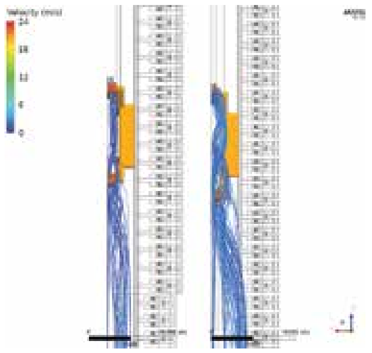

Figure 6: Air streams released from shearer cutting drums to predict dust flow, left: Cutting with drums up, right: Cutting with drums down.

pressure is also clear from the data, it was observed during testing that coverage was still relatively good at 60 bar but limited when running at 16 bar. The reduction in dust when increasing the pressure from 60 bar to 100 bar strongly supports previous reports that utilising an increased pressure to produce a greater concentration of finer droplets results in a significant improvement in dust capture efficiency. At 60 bar the droplet size produced is approximately double the droplet size produced at 100 bar.

It was not possible to utilise two dust monitors to measure the change in dust across the trial section of the longwall, instead the next best option was to undertake testing separately upstream of the system and remove the average dust concentration measured from the measurements taken downstream. To remove the affect of the upstream dust on the results, the dust monitor was placed on the #3 roof support over several shears allowing for a representative average dust concentration to be established. Figure 5 shows the dust concentration readings with the average incoming dust removed, for clarity this has been shown for just the 100 bar and system off readings. This data shows a very positive outcome indicating that over 80 per cent of the dust generated by the movement of supports #4-9 was removed by the implementation of the system.

The second stage of the trial was to evaluate the performance of the micro-mist nozzles in the canopy of a series of roof supports (supports #5-16) to reduce dust generated by the shearer. For this trial a pair of micro-mist nozzles were mounted on each roof support replacing the OEM provided nozzles. CFD was utilised in this case to analyse airflow around the shearer, firstly to predicted typical air velocity (found to be around three metres per second), and secondly to predict dust flow which was achieved by releasing streamlines of air from the shearer cutting drums under the assumption that the dust particles follow the same path as the air. Figure 7 compares the predicted dust flow between the shearer cutting the roof to when it is cutting the floor; it is evident that the flow is dispersed out from the face by a much greater amount when the shearer is cutting the floor, this would likely contribute to greater levels of dust in the walkway. As this greater dispersion is occurring when the shearer is cutting the floor it was important that the installed sprays have sufficient energy to reach the floor, as such the nozzles installed for this case were operated at 120 bar with a flow of 4.3 litres per minute corresponding to a droplet size of 40 µm. Simulation of spray dispersion also aided in selecting the number of sprays that should be operated at a time; the initial simulation consisted of only two nozzles per drum being operated, however, it was quickly found that this did not provide the required coverage, instead it was found that at least four sprays should be operated to achieve adequate coverage of each drum.

Operation of the sprays on each support was controlled based on the position of the shearer with a headway of three in front and behind the shearer centreline, for underground trials it was decided that three canopy spray sets operating in front and two sets operating behind would be tested. To evaluate this system, the dust monitor was placed on the #18 roof support with the monitor probe placed approximately one metre from the outside of the roof support legs towards the face. The dust concentration in this location was then recorded over several shears with the spray system operating at full pressure (120 bar) and with the system off. Data collected from

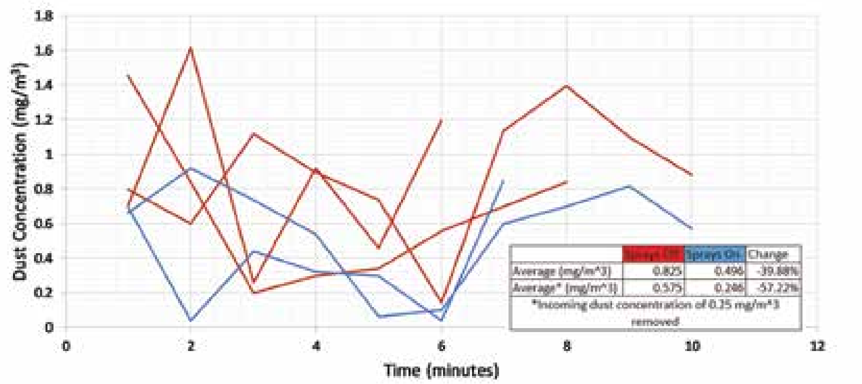

Figure 7: Dust concentrations measured during underground trials of roof support canopy sprays for reduction of dust generated by the shearer.

these trials are shown in Figure 7, this data represents dust measured during the period in which the shearer cut from roof support #22 to the main-gate and back, note that the time taken to do this varied from shear to shear.

The data recorded does indicate that a reduction in dust concentration was achieved. Overall, a reduction of approximately 40 per cent (57 per cent when dust from upstream sources is removed) of dust generated by the shearer was achieved. It should be noted that without the system operating there were already a significant number of sprays (>150 litres per minute) operating on the shearer and the fact that a reduction in dust was still achieved provides evidence to support that fine mist sprays (rather than coarse droplet sprays) are required for effective dust capture; it is entirely possible that a more significant reduction in dust could be achieved by simply changing some of the nozzles on the shearer to micro-mist nozzles.

Conclusion

Solutions do exist to control dust and that with proper design and analysis a positive result can be achieved. The use of CFD has been proven to be an important tool in analysing air and dust flow in a longwall mine so that dust suppression nozzles can be applied at the correct pressure and positions to result in the greatest dust capture. B

ACKNOWLEDGEMENTS

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