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EVALUATION OF A CONVENTIONAL DUST VENTILATION/COLLECTION SYSTEM IN AN UNDERGROUND MINE CRUSHING PLANT

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ABSTRACT

Air flow and dust dispersion in an existing underground mine crushing plant was modeled using (Computational Fluid Dynamics) CFD. In the conventional system, investigated in the present paper, the outgoing dust laden air was collected through an exit in the ceiling of the chamber (tipple) housing the ore collection bin. The dust collection performance of the system is summarised. The detail results are presented in the form of velocity vectors and dust concentration iso-surface contours. The time dependent dust concentration iso-surfaces are also presented. Dispersion of dust was found to produce cloud engulfing most of the tipple volume.

Keywords: dust ventilation modeling.

1. INTRODUCTION

Extraction of ore using block caving method is common in many underground mines. The ore extracted from draw point is hauled to underground crushing station using load haul dump (LHD) trucks and tipped or dropped into ore or ROM bin. Dust is released during the tipping process. The released dust often causes visibility problem to the LHD drivers. The released/dispersed dust is expected go out along with the outgoing ventilation air. In the conventional approach the outgoing dust laden air is collected through an exit in the ceiling. The dispersion of dust is governed by local airflow controlled by the mechanical ventilation system and is made very complex by the localised turbulent air motion generated by large volumes of material undergoing drop feed [1]. Computational Fluid Dynamics (CFD) simulation has been successfully used in the past [2] to evaluate the ventilation of underground crushing plant. The study [2] also carried out experimentation to qualitatively validate the CFD results and gain more insight into the physics of the dust dispersion by the drop feed.

This paper undertakes CFD modelling of a conventional dust collection systems in operation, details not disclosed for confidentiality reasons. Dust laden air was collected through an exit in the ceiling of the tipple. Fig. 1 shows the geometry of the tipple investigated in this study. The merits of the proposed dust collection system were evaluated and remarks/recommendations made. Simulations were conducted for three cases: empty, half, and full ore bin scenarios.

The paper presents the flow geometries investigated, computational grid used for modelling and the computational results obtained under the specified operating conditions. The CFD software FIRE [3] was used for this investigation.

2. COMPUTATIONAL METHOD

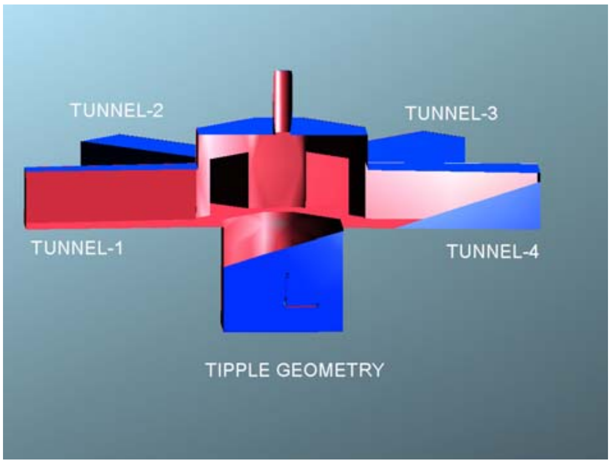

Fig 1: Geometry of the tipple (a cut away view)

A typical computational grid arrangement, out of the three used for different bin content scenarios (empty, half empty & full) is shown in Fig. 2. The solution domain and the computational grids were constructed from the CAD drawings. Time averaged equations were solved to obtain the values of velocities, pressure, dust concentrations and turbulence parameters. The multi-phase capability available in FIRE was used to model the air-dust flow system. Air was considered as the continuous phase (1^{st} Phase) and dust, with a density of 2000kg/m^3 and particle size of 5 micron, was considered as the dispersed (2^{nd} phase). Both transient and steady state conditions were modelled. In the transient or time dependent situation, efforts were made to simulate the cyclic loading pattern observed in the real life operation (one LHD feed per min). A 5m^3 of air-dust mixture (representing the volume of air displaced from the bin by each LHD feed) with a dust loading of 1% was released from the bin over a period of 5 sec. (i.e a flow rate of 1m^3/sec) The cycle was repeated every 60 seconds and a total of 10 cycles, i.e. a total of 600 seconds in real time was simulated. Under the steady state situation a continuous release of 5m^3/60 = 0.0833m^3/sec. of air-dust mixture was maintained from the bottom of the bin. The simulations were carried out under iso-thermal (20^{0}C) conditions. The volume flow rates of air through each tunnel and the air-dust mixture released from the bin, for all the three case scenarios investigated, are given in the table-1.

Table 1: Volume flow rates (boundary conditions)

Inlets	Air Volume flow rates m^3/sec		Dust loading % volume
Tunnel-1	20.1		0.0
Tunnel-2	3.3		0.0
Tunnel-3	10.8		0.0
Tunnel-4	22.6		0.0
Bin (bottom of bin)	**Steady** 0.0833	**Transient (60 sec/cycle)** 1.0 for first 5 sec 0.0 for next 55 sec	1.0

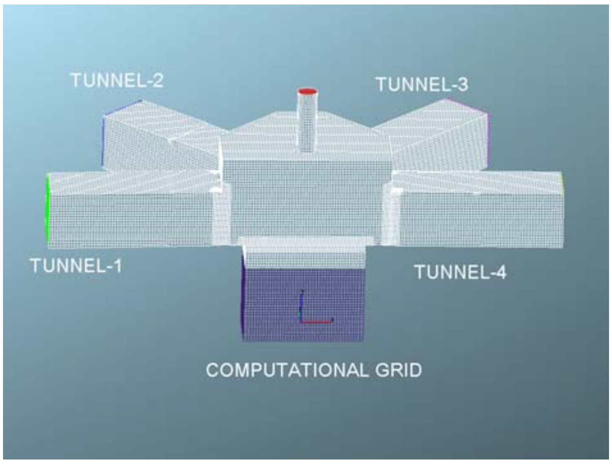

Fig 2: A typical computational grid used

3. RESULTS AND DISCUSSIONS

The overall dust collection performance is summarised in table-2. The detail results are presented in the form of velocity vectors on vertical and horizontal planes and dust concentration iso-surface contours in the solution domain. As the time dependent effects were introduced through air-dust mixture released from the bottom of the bin (see Table-1), it was not expected to alter the overall flow dynamics of the domain substantially. However, the dust concentration pattern will be altered. Hence, the dust concentration iso-surface contours obtained for both transient and steady state cases are presented in this paper. The time dependent videos of dust concentration iso-surfaces were also developed but could not be made available with this paper. The velocity vectors obtained for steady state cases are presented in this paper.

3.1 Dust collection performance summary

Dust released and dust collected under the steady state cases are presented in table-2. Dust was found to produce dust cloud engulfing most of the tipple volume (Fig. 3f & 3g). The movements of the LHDs have the potential of dispersing the dust into the tunnel and aggravate the visibility for the LHD drivers.

Table 2: Dust collection summary

Dust collection For exit through 20cm holes in the bin	Dust released from the bottom of the bin Kg/sec	Dust collected Kg/sec	Remarks
Empty bin	1.67	0.9	55% dust is extracted, the rest is **NOT contained within the bin and forms dust cloud.**
Half-empty bin	1.67	1.08	65% dust is extracted, the rest is **NOT contained within the bin and forms dust cloud.**
Full bin	1.67	1.09	65% dust is extracted, the rest is **NOT contained within the bin and forms dust cloud.**

3.2 Presentation of detail results

The velocity vectors on a vertical plane through the centre of Tunnels 1 & 4, (Fig. 3a) show that the majority of the flow travels towards the exit duct in the ceiling. Two vortices are formed in the corners near the ceiling. The shearing action of the flow from the tunnels appears to pick up some dust-laden air from the bin. The velocity vectors inside the bin are not well oriented to flow towards the exit duct. They rather form weak disorganised vortices that have the potential to carry dust sidewise and form dust cloud, as is evident in the dust iso-contours (Figs. 3f & 3g).

The velocity vectors in Fig. 3b show that the flow doesn’t have enough momentum (due to small volume flow rate through tunnel-2, see table-1) to penetrate into the tipple and quickly bends towards the ceiling along with dust laden flow coming from the bin. This flow has the potential of feeding the dust into the corner vortices near ceiling and form dust cloud. Flow through tunnel-3 (Fig. 3c) show similar behavior to that observed for tunnels 1 & 4 (Fig. 3a). By adjusting/balancing the flow rates through the tunnels it may be possible to reduce the size of vortices and hence the potential of dust cloud formation near the ceiling of the tipple.

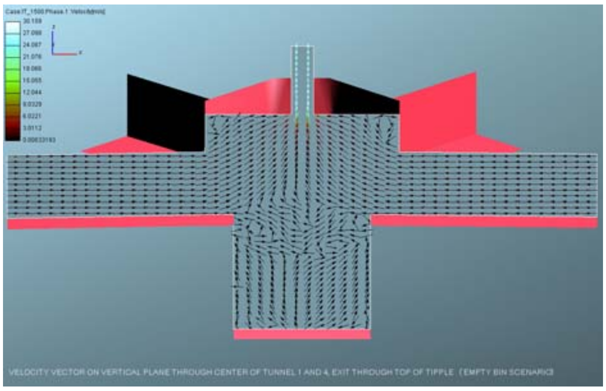

Fig 3(a): Velocity vectors on a vertical plane through the centre of Tunnel 1 & 4 (empty bin scenario)

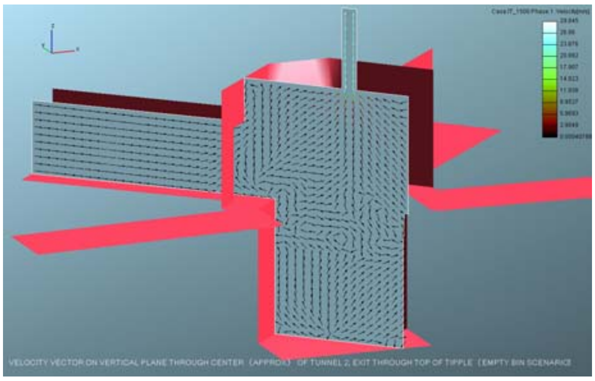

Fig 3(b): Velocity vectors on a vertical plane through the centre of Tunnel 2 (empty bin scenario)

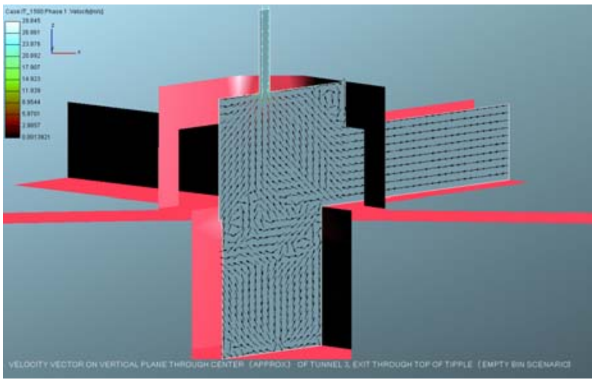

Fig 3(c): Velocity vectors on a vertical plane through the centre of Tunnel 3 (empty bin scenario)

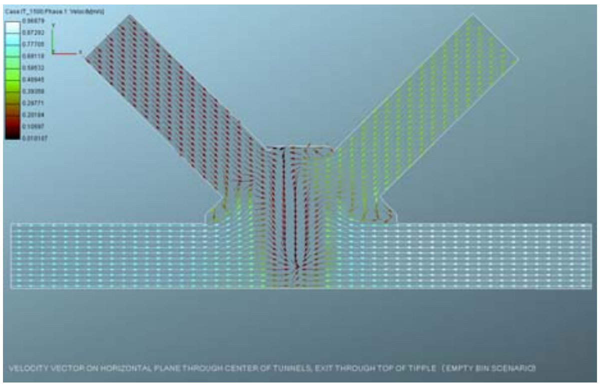

Fig 3(d): Velocity vectors on a horizontal plane through the centre of Tunnels (empty bin scenario)

Velocity vectors (Fig. 3d) show that the higher flow rates through tunnels-1 & 4 leads to greater penetration into the tipple, whereas the least flow rate through tunnel-2 leads to lowest penetration. Velocity vectors (Figs. 3e) on a horizontal plane near the roof of the Tipple clearly show the formation of vortices capable of forcing the dust laden air downwards and form dust cloud.

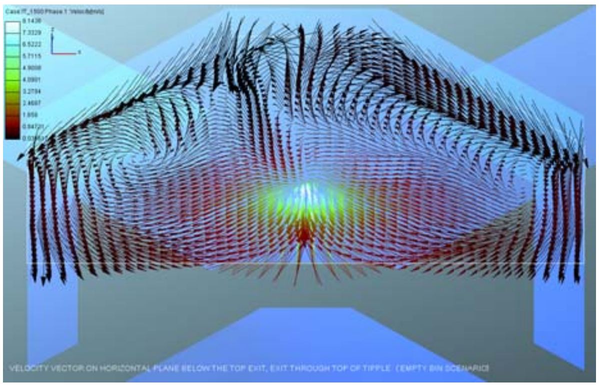

Fig 3e: Velocity vectors on a horizontal plane near the ceiling (empty bin scenario)

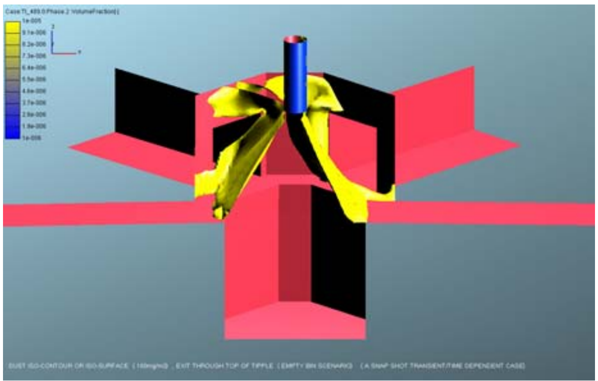

Fig 3(f): Dust iso-contours or iso-surface (100mg/m^3) (empty bin scenario) (A snap shot of transient/time dependent case)

Dust iso-contours or iso-surface (100mg/m^3) presented in Figs. 5f & 5g, clearly show the formation of dust cloud engulfing most of the tipple volume. It may be mentioned here that the dust concentration inside the iso-surface envelope is greater than 100mg/m^3. The dust generated by LHD movement (ignored in this study) has the potential to aggravate the situation.

The dust iso-contours for half-empty and full bin scenarios presented in Figs. 4a & 4b show similar behavior to that observed for empty bin scenario presented above in Fig. 3f. However, the formation of dust cloud is more pronounced for the full bin case (Fig. 4b). Which along with the movements of the LHDs have the potential of dispersing the dust into the tunnel and aggravate the visibility for the LHD drivers.

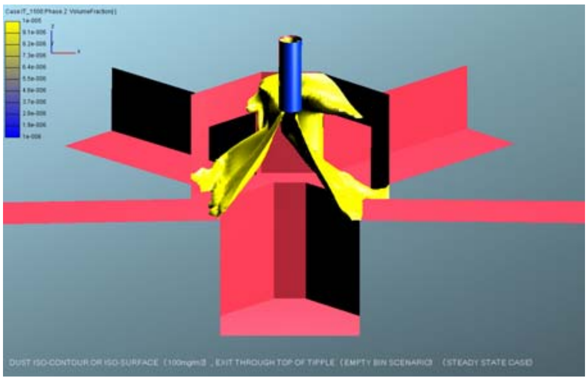

Fig 3g: Dust iso-contours or iso-surface (100mg/m^3) (empty bin scenario) (steady state case)

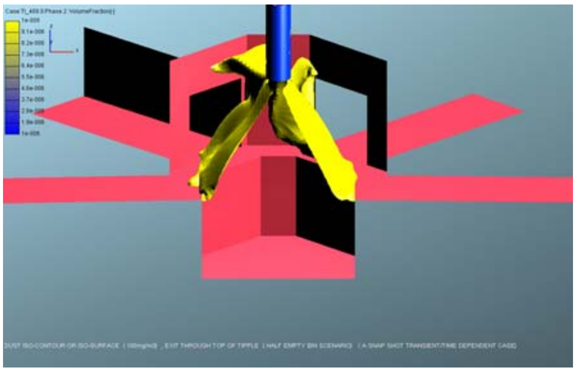

Fig 4(a): Dust iso-contours or iso-surface (100mg/m^3) (half-empty bin scenario) (A snap shot of transient/time dependent case)

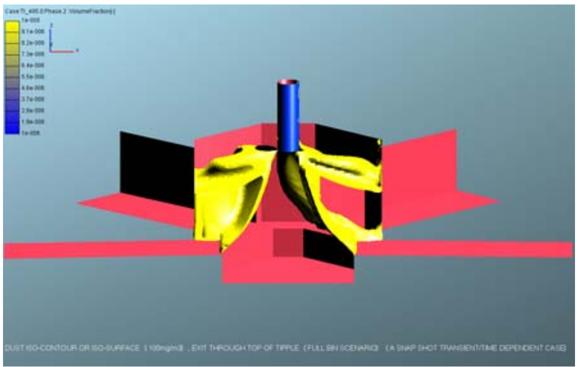

Fig 4(b): Dust iso-contours or iso-surface (100mg/m^3) (full bin scenario) (A snap shot of transient/time dependent case)

4. REFERENCES

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