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Coal mine ventilation: a study of the use of ventilation in the production zone

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ABSTRACT

The blind headings created in room and pillar mining are known to be the high risk areas of the coal mine, since this is where the coal production is actually taking place and hence the liberation of maximum quantity of methane. The ventilation of this region called the localized ventilation is carried out using auxiliary ventilation devices. This ventilation may be planned and be the subject of mine standards, but it is not very well understood and implementation on a day to day basis is usually left to the first level of supervisory staff. Majority of the methane explosions have been found to occur in these working areas and blind headings. The correct use of auxiliary ventilation devices can only be carried out once the effect of the system variables associated with each device is very well understood and can be calculated mathematically. Presently, no mathematical models or empirical formulas exist to estimate the effect of the associated system variables on the flow rates close to the face of the heading. The extent of ventilation of a heading ventilated without the use of any auxiliary device is not clear. Furthermore, to design additional engineering solutions, the flow patterns inside these heading ventilated with the auxiliary ventilation devices needs to be understood.

The study of the face ventilation systems and the effect of the system variables associated system with each auxiliary ventilation device can be carried out experimentally, but doing a large number of experiments underground is very difficult as it disturbs the mine production cycles. Furthermore, studying the flow patterns experimentally is even more cumbersome, and can only be done to some extent using smoke or tracer gas. Therefore, Computational Fluid Dynamic's (CFD) advanced numerical code ANSYS Fluent was used to study the effect of a number of system variables associated with the face ventilation systems used in blind headings.

As part of the procedure, the CFD model used was validated using four validation studies, in which the numerical results were compared with the actual experimental results. The numerical results differed to a maximum of 10% for all the experimental results. The system variables associated with ventilation of a heading, without the use of any auxiliary device, with the use of Line Brattice (LB) and fan with duct were

selected. A range of values was chosen for each variable, and scenarios were created using every possible combination of these variables. All the scenarios were simulated in Ansys Fluent, the air flow rates, air velocities, velocity vectors, and velocity contours were calculated and drawn at different locations inside the heading. The effect of each system variable was found using a comparative analysis. The results were represented in simple user-friendly form and can be used to estimate the air flows at the exit of the LB and face of the heading for various settings of the LB and fan and duct face ventilation systems.

The analysis of the ventilation of a heading without the use of LB shows that a maximum penetration depth is found with the Last Through Road (LTR) velocity of 1.35m/s. The flow rates and the maximum axial velocities increase with the increase in the LTR velocity up to a depth of 10m (maximum air flowing into a heading of 1.26m^3/s and 1.58m^3/s is found for the 3m and 4m high heading using 2m/s LTR velocity).

For the LB ventilation system the LTR velocities, heading height, length of the LB in the LTR and heading, angle of the LB in LTR, and distance of the LB to the wall of the heading (side wall) were varied to identify clearly the effect of these control variables, on the flow rate at the exit of the LB, and close to the face of the heading. The flow rate at the exit of the LB is found to be proportional to the product of the distance of the LB to the wall in the LTR and heading. The flow rate at the exit of the LB, face of the heading, and inside the heading is found proportional to the LTR velocity and height of the heading. It is found that a minimum length of LB is associated with each distance of the LB to the wall in the heading, to maximize the delivery of air close to the face of the heading. This length is found to be equal to 15m for 1m LB to wall distance, and 10m for 0.5m LB to wall distance. Mathematical models were developed to estimate the effect of each studied system variables on the flow rates at the exit of the LB and close to face of the heading.

For the fan and duct systems the length, diameter, and the fan design flow rates were varied. It is found that for a force fan duct system only a maximum of 50% of the total air that reaches the face is fresh and the remaining 50% is recirculated air. The flow rate with the exhaust fan system is found to be much lower than the force fan duct system. It

increases with the reduction in duct mouth to heading face distance, and increase in duct diameter. Mathematical models are developed to calculate the flow rates at the face of the heading using the effect of each studied system variable.

The research reveals that the ANSYS numerical code is an appropriate tool to evaluate the face ventilation of a heading in a three dimensional environment using full scale models. The South African coal mining industry can benefit from the outcomes of this study, specially the mathematical models, in a number of ways. Ventilation engineers can now estimate the flow rates close to the face of the heading for different practical mining scenarios and ensure sufficient ventilation by using the appropriate auxiliary ventilation settings. The results can easily be developed into training aids using easy to use excel spread sheets to ensure that mineworkers at the coal face have a better understanding of the working of the auxiliary ventilation devices. It can also serve Academia as part of the curriculum to teach the future mining engineers how the different variables associated with the auxiliary ventilation system affect the ventilation in a heading. The research therefore, has the potential to provide a significant step toward, understanding airflow rates delivered by the auxiliary devices close to the face of the heading and the air flow patterns inside the heading.