Abstract

Shock losses contribute to a significant part of the mine ventilation pressure loss. Empirically established shock loss factors and drag coefficient values are available in literature for predicting the shock loss due to scenarios of bends and area changes, and scenarios of regular shaped single obstruction in the airway respectively. In case of multiple obstructions in line with the airflow and repeating at regular intervals, the phenomenon of interference affects the shock loss. There are number of regularly spaced obstruction scenarios in mine ventilation such as shaft buntons, supports in a roadway, power supports in longwall face, multi-deck conveyance in a shaft and train of mine cars in a roadway. The literature for the estimation of shock loss factors due to these regularly spaced obstructions is limited and dated. In this study, certain geometries related to train of mine cars in a roadway and shaft buntons are examined using scale model investigations and numerical investigations with a view to create better prediction models for loss estimation.

In scale model investigations, similitude conditions are addressed so that the pressure ratios and dimensionless parameters from the scale model represent the real-life flow behaviour. High precision instruments are used for measurement of the pressure loss in the scale models and variable frequency drives are used to control the flow through the model. Numerical investigations are performed using finite volume method with the help of ANSYS fluent 16.2 software. RANS group of turbulence models are used for solving the incompressible, steady state turbulent flow considered in the study.

The shock loss factors from the experimental results of train of mine cars are compared with the values from prediction methods available in the literature. The comparison shows that, the available methods fail to predict the shock loss factors due to train of mine cars with meaningful accuracy. The Weeks' model for shock loss factors due to train of mine cars over predicted the shock loss factor by 7 to 15 times depending on the number of mine cars in the train. Shock loss factors predicted from Stevenson's model for multi-deck conveyance in a shaft matched better with the experimental results compared to other prediction methods in the literature. However, the comparison was limited considering that the Stevenson's model accounts for four decks. A new and better prediction model for shock loss factor of n number of loaded mine cars in airway is constructed using the experimental results, having the form $X = 0.2 + 0.05n$, when about 15% of the airway cross-section is occupied by the projected area of the train.

Four different RANS turbulence models and two methods of boundary layer resolution are considered for the numerical investigation of the shock loss due to train of mine cars in the roadway. The vortex regions around the mine cars from different simulation conditions are visualized with the help of the CFD. The mine cars geometry in numerical simulations is simplified by assuming a covered top surface. Experiments with covered top mine cars are

performed to enable comparison between experimental and numerical results. By comparing the numerical and experimental results of train of mine cars, SST k-ω turbulence model with enhanced wall function method is identified as the most satisfactory simulation condition for simulation of shock loss under study, and the numerical simulations of shock loss due to shaft buntons are performed using this simulation condition. The simulations predicted slightly lower shock loss (about 10% less) when compared with the experimental results. The lower shock loss values predicted by the numerical studies are likely on account of the idealized geometries used in numerical studies.

Two factors, the bunton shape (C_D) and the spacing-width ratio (s/w), are considered for the scale model studies and numerical investigations on the shock loss due to shaft buntons. The shock loss factors of circular-section and I-section buntons from numerical results matched closely with the scale model experimental results. Comparing the results with Bromilow's interference factor (F) model for shaft buntons, it is found that the Bromilow's model is suitable for predicting shock loss due to the circular-section buntons but fails for the I-section buntons. Numerical simulations, factoring the position of bunton in the shaft cross section (d/R), are performed for both the circular and I-section shapes. From the numerical results is found that the interference behavior changes with the shape of the buntons and the position of buntons in the shaft. Shock loss factor of I-section buntons close to the shaft walls are significantly less due to the proximity interference with the shaft walls.

Non-linear regression analysis using Gauss–Newton algorithm is employed to find the parameters in the equation. Interference factor model (F_1) developed for shaft buntons with C_D between 1.2 and 2.75 using numerical results is $F_1 = 0.01 + \frac{0.02(\frac{s}{w})}{C_D} + 0.32\left(1 - \left(\frac{d}{R}\right)\right) * C_D$. I-section is the most used bunton shape in the mineshafts and installed with web of the I-section in line with the airflow. For this scenario, a interference model (F_2) with better accuracy is suggested as $F_2 = 0.59e^{-\left(\frac{\left(\frac{d}{R}-0.5\right)}{0.25}\right)^2} + \left(0.007 * \left(\frac{\mathrm{d}}{\mathrm{R}}\right) * \left(\frac{\mathrm{s}}{w}\right)\right)$. The new interference factor models proposed in this study are useful in predicting the shock loss due to shaft buntons with better accuracy.