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Study on the influence of some ventilation parameters on dust dispersion in heading face coal mine using CFD numerical model

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This article provides an overview of the coal mining industry in Vietnam, emphasizing the increase in coal production and the consequent environmental and occupational health challenges. The main concern is the high concentration of coal dust generated during the drilling and blasting processes in large-scale mining operations. The coal dust poses a significant threat to the progress of tunnel construction and, more importantly, to the health of the workforce, potentially leading to respiratory issues and other health-related problems. The article mentions the existing research and efforts to control coal dust in Vietnam, including previous studies and international research using Computational Fluid Dynamics (CFD) modeling methods. The focus of the research discussed is on analyzing the movement of air and dust particles within mine tunnels, considering various factors such as wind velocities and the placement of ventilation outlets at different heights. The objective is to determine how these ventilation parameters influence dust concentration within tunnels and its dispersion over time, with the ultimate goal of supporting measures to mitigate dust and protect workers' health.

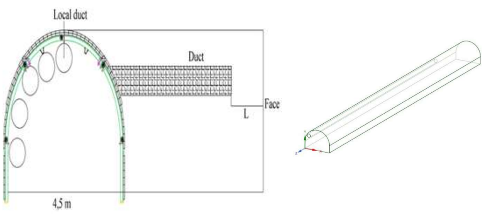


Figure 1. Tunnel model and air duct suspension positions

Analysis of the Impact of Air Velocity on Dust Dispersion in the tunnel

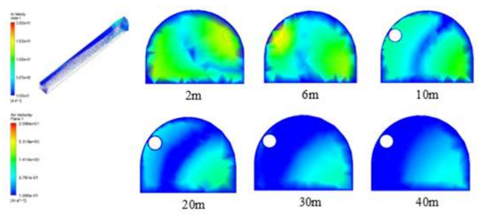


Figure 1. Velocity Distribution on Longitudinal Cross-Section along the heading face with V = 9 m/s.

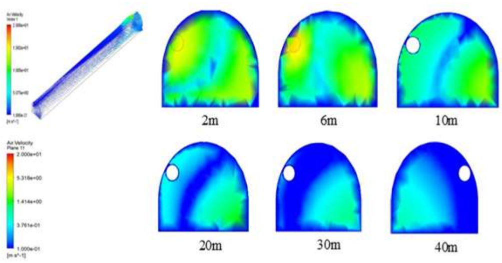


Figure 2. Velocity Distribution on Longitudinal Cross-Section along the heading face with V = 12m/s.

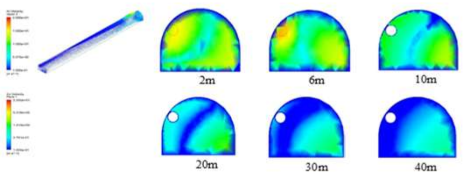


Figure 3. Velocity Distribution on Longitudinal Cross-Section along the heading face with V = 15 m/s

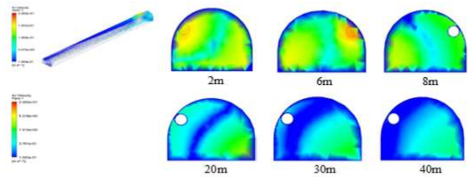
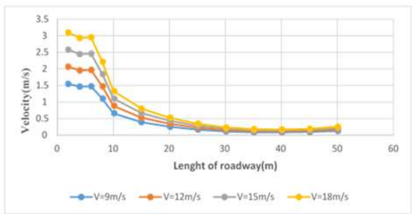


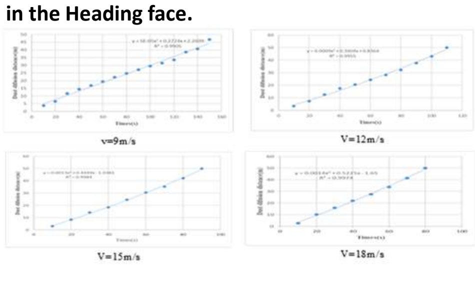
Figure 4. Velocity Distribution on Longitudinal Cross-Section along the heading face with V = 18 m/s

Figure 1-4, based on longitudinal cross-sections along the tunnel, demonstrates that within approximately 20 m from the tunnel's back, an uneven wind distribution exists. Higher wind velocities are concentrated on the right side of the tunnel, while lower velocities are found on the left side. The central portion experiences the lowest wind velocity within this distance. This indicates that the wind flow becomes more stable, reducing small variations. This is attributed to the influence of the wind flow rebounding after colliding with the tunnel wall and the wind exiting the ventilation outlet, which generates a vortex region, resulting in lower wind velocities within this area..



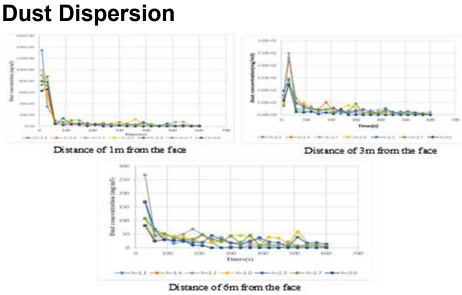
In Figure 5, we can observe that all four wind velocity models consistently indicate that after wind exits the ventilation outlet, the wind velocity gradually decreases. Upon collision with the tunnel, the wind reverses its direction within approximately 10 meters from the tunnel's face. At this point, the wind velocity experiences a sharp decrease, followed by a gradual and stable reduction.

Influence of Wind Velocity on Dust Distribution in the Heading face.



In Figure 8, the graph illustrates the relationship between the distance of dust diffusion within the tunnel over time with various velocity parameters. This relationship is represented by a quadratic function. Higher wind velocities result in faster and more extended dust diffusion within the same time

Influence of Ventilation Duct Position on Dust Dispersion



In models with different heights (h=1.1 to h=3.0), the model with h=1.1 had the highest dust concentration, about 1344 mg/m3, while the model with the lowest h=3.0, about 631 mg/m3. For models from h=1.1 to h=2.7, it took about 450-480 seconds for dust concentrations to fall below 10 mg/m3, while models h=3.0 reached this level in about 300 seconds. At distances of 3m and 6m from the source, the results also showed that, in about 10 seconds, the dust concentration was lower for the model with h = 3.0 than for other locations.. Therefore, the h=3.0 position of the ventilation duct proved to be more effective in reducing dust concentrations in the work area for workers, as shown from the results.

CONCLUSION

Within the scope of the study, wind velocity significantly affects the dispersion and settling of dust within the tunnel. Higher wind velocities lead to more effective dust reduction.

After blasting, dust is ejected into the tunnel at high speeds due to the shockwave effect and subsequently diffuses through the tunnel entrance under the influence of the wind. Dust concentration decreases over time. The fastest decrease occurs within the first 100 seconds, followed by a slower decline over the next 120 seconds. Ultimately, 600 seconds after blasting, dust concentration within the tunnel drops below 10 mg/m3.

Variations in the height of the ventilation duct affect the shape of the counterflowing liquid, the distribution of wind velocity in the vicinity, the structure of vortices, and the degree of mixing in the circulating airflow. When the ventilation duct is placed at the center of the tunnel, the airflow is weakest, which is advantageous for dust removal on the road surface. Considering the distribution of wind velocity, flow field structures, and dust dispersion characteristics, it is observed that when the height of the ventilation duct is h=3.0, the ventilation and dust extraction efficiency within the tunnel is optimal.