JOURNAL OF MULTIDISCIPLINARY SCIENCES AND INNOVATIONS
VOLUME 04, ISSUE 10
MOPNTHLY JOURNALS
ISSN NUMBER: 2751-4390
IMPACT FACTOR: 9,08

VENTILATION OF AN OPEN-PIT MINE USING WIND ENERGY

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Annotation: This study examines the principles of air movement within open-pit mines and the natural forces that influence these movements. Various ventilation schemes are analyzed, including direct-flow, recirculation, convection, and inversion schemes, with a focus on wind-driven ventilation. The formation of direct-flow and recirculation schemes depends largely on the geometry of the pit and the slope angle of the pit walls. Direct-flow ventilation ensures efficient removal of harmful substances without creating stagnant zones, while recirculating ventilation allows continuous extraction of pollutants through a stable mass core. Additionally, combined ventilation schemes (direct-flow–recirculation and recirculation–direct-flow) are used for pits with varying geometry or large dimensions along the wind direction. The study highlights the significance of wind speed, pit wall angles, and pit geometry in designing effective natural ventilation for open-pit mines.

Keywords: Open-pit mine, Ventilation schemes, Wind energy, Direct-flow ventilation, Recirculation ventilation, Airflow dynamics, Pollutant removal, Pit geometry

Introduction: As noted above, the multiple movement laws of air within an open-pit mine and the natural forces that form these movements are manifested in several main schemes, known as open-pit mine ventilation schemes.

In ventilating open-pit mines using wind energy, four main ventilation schemes can be used: direct-flow, recirculation, convection, and inversion ventilation schemes. The first two are formed by wind energy, while the third and fourth are formed by thermal energy.

When the wind energy (speed) is high, the formation of direct or recirculating airflow ventilation schemes in the open-pit mine mainly depends on the geometry of the pit (the slope angle of the pit walls).

If the wind speed on the surface of the Earth exceeds 0.8–1.0 m/s, and the slope angle of the pit wall opposite to the wind direction is $\alpha_1 \leq 15°$, a direct-flow ventilation scheme is formed. In this scheme, the air stream moves along the surface layer (plane a–a), reaches point O (Fig. 1), and then expands toward the pit bottom. As a result of the decrease in air velocity, an “OAO' cap” is formed at the top of the pit.

In the direct-flow ventilation scheme, there are no large stagnant zones where harmful substances could accumulate. The efficiency of removing harmful gases in this scheme is significantly higher than in other schemes. In this case, harmful substances pollute only the air directly in front of their emission sources, without causing overall atmospheric pollution within the pit area.

The smaller the slope angle of the pit wall, the better the conditions for removing harmful substances from the pit, since with an increase in the slope angle, the degree of airflow expansion increases while air velocity decreases.

However, in this ventilation scheme, the ventilation of the windward and leeward pit walls is not uniform. In the direct-flow ventilation scheme, the leeward wall of the pit is always ventilated by clean air entering from the surface, while the windward wall is ventilated by air that has already passed through the leeward wall and the pit bottom.

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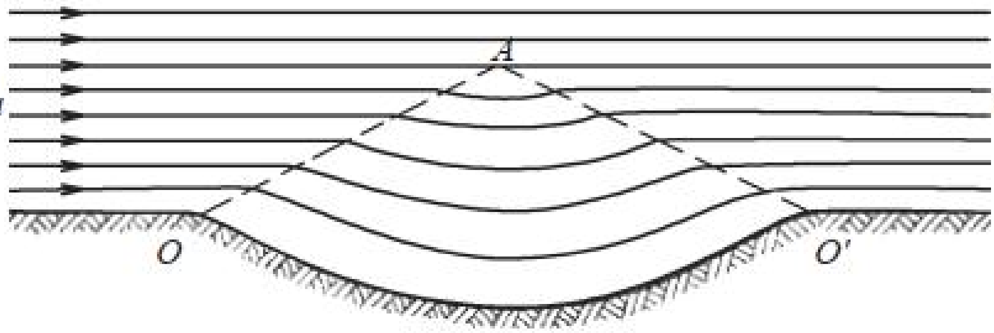

Fig. 1 – Diagram of wind flow expansion above the open-pit mine.

When the wind speed exceeds 0.8–1.0 m/s and the slope angle of the pit wall opposite to the wind direction is $\alpha_1 > 15°$, a recirculating ventilation scheme is formed (Fig. 2).

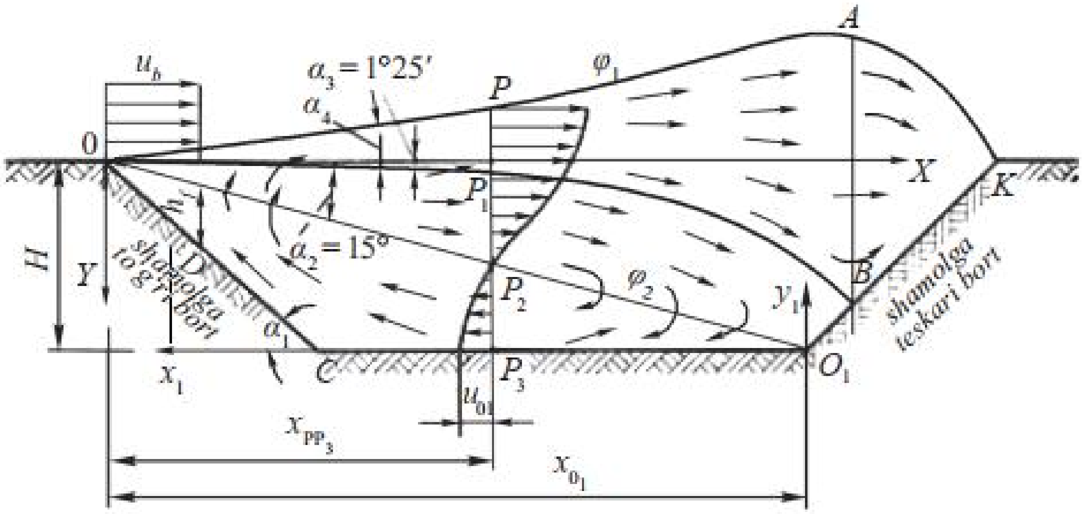

Fig. 2 – Scheme of air recirculation movement in an open-pit mine.

When the open-pit mine is ventilated according to the recirculating flow scheme, harmful substances contained in the air are continuously removed from the pit through a stable mass core. Harmful substances enter this core from its initial section, the P_2OP_1 zone (see Fig. 2). The mixture of air and harmful substances moves downward in a recirculating motion below the P_2P_1B boundary.

According to the law of mass conservation, the difference between the amount of harmful substances entering the recirculation zone and the amount discharged from it over a certain period of time is equal to the change in the amount of harmful substances within the recirculation zone during that same period, that is:

$G_P - G_y = \Delta G$,

Here, G_p is the amount of harmful substances that entered the recirculation zone during a given time interval; G_γ is the amount of harmful substances removed from the recirculation zone during the same time interval; and ΔG is the change in the amount of harmful substances within the recirculation zone during that period.

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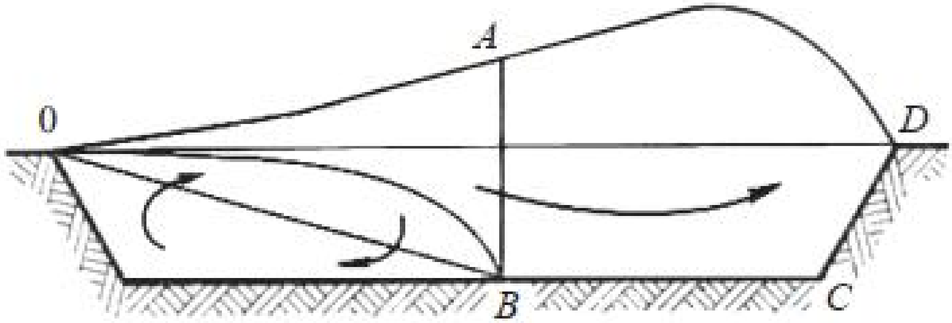

Fig. 3 – Ventilation of an open-pit mine under the recirculating–direct flow scheme.

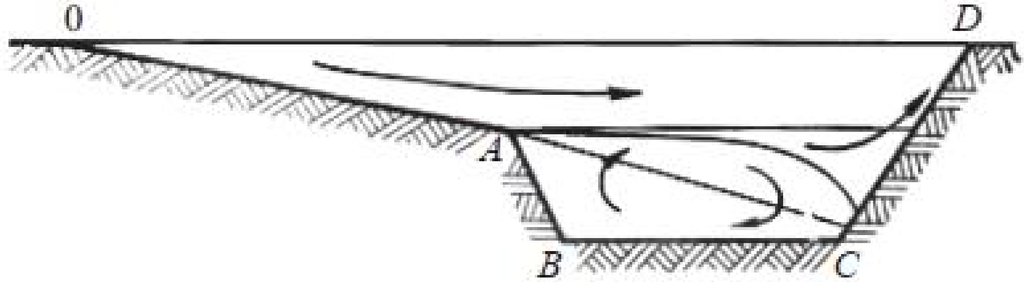

Fig. 4 – Ventilation of an open-pit mine under the direct flow–recirculating scheme.

In some cases, due to the actual geometric shapes of open-pit mines, a part of the pit a rea may be ventilated according to the direct-flow scheme, while another part operates under the recirculating-flow scheme, that is, using a combination of both schemes.

For example, when the pit has large dimensions along the wind direction, ventilation can be carried out using a recirculating–direct flow combined scheme (see Fig. 3). In this scheme, the lower boundary of flow type I intersects the pit bottom at a certain point B. The right side of this point (section B–C–D) is ventilated according to the direct-flow scheme, while the left side of the pit from section A–B is ventilated according to the recirculating scheme.

If the slope angle of the pit wall opposite to the wind direction varies, the pit area is ventilated using a combination of direct-flow and recirculating-flow schemes (see Fig. 4).

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