APPLING HIGH WATER PRESSURES EJECTOR SYSTEM TO CONTROL DUST IN QUANG NINH UNDERGROUND COAL MINE

Phuong Thao Dang[1], Van Thao Le[2]

[1] Hanoi University of Mining and Geology, 18 Vien Street, Duc Thang Ward, Bac Tu Liem District, Hanoi, Vietnam; E-mail: dangphuongthao@humg.edu.vn
[2]Vietnam Mining Science and Technology Association, 655 Pham Van Dong, Co Nhue 1 Ward, Bac Tu Liem District, Hanoi, Vietnam; E-mail: thaolv51@gmail.com
Corresponding author: dangphuongthao@humg.edu.vn

ABSTRACT. In recent years, in Quang Ninh coal underground mine, longwall mining has been increasingly applied to meet the energy demand. This has resulted in the potential for increased mining dust. Coal dust is not only harmful to workers but also creates a risk for coal dust explosions in the mine. Therefore, in order to control the mine dust problem, it is necessary to develop a set of dust removal equipment suitable for underground coal mining. High-pressure water ejector system is selected to control dust in Quang Ninh mine. In addition, parameters and criteria for the design of the high-pressure water jet ejector systems have been presented.

Key words: high pressure water ejector system; dust control; air dust reduction; dust hazard

Introduction

According to the Vietnam coal industry development plan, the output of coal mining in the coming years will reach 70 million tons, and the output of underground coal mines will account for about 80% of them. The total length of new driven roadways and longwalls is getting greater to expand mining areas and growing coal production. This has resulted in increasing the amount of dust generated in the mine, especially the dust generated in the driven roadways and in longwalls and has led to exposing workers to dust levels as well as increasing the hazard of coal dust explosion.

According to the Vietnam regulations, respirable dust and total dust concentration over an 8-hour shift must be equal to 2 mg/m^3 and 3 mg/m^3, respectively. In some workplaces, the total dust concentrations exceed approximately 15-30 times the total dust standard, the respirable dust concentrations exceed the respirable dust standard 9-11 times (Dang et al. 2016). Coal dust is harmful, causing about 1000 pneumoconiosis cases per year and the cumulative pneumoconiosis cases among workers are 21000, accounting for 75,7% of the total occupational disease incidence.

Therefore, this paper examines a serious problem of dust pollution and dust control technology in Quang Ninh coal mine. High-pressure water ejector system is selected to prevent dust. In addition, parameters and criteria for the design of the high-pressure water jet ejector systems have been presented.

Materials and methods

Dust control methods are applied in Vietnam

There are many solutions available for dust control, but in the Vietnam coal underground mines, the use of ventilation and spray water are the most commonly used methods of dust control. In fact, water sprays are considered to be the most economical and technically feasible means of reducing dust concentrations in underground coal mines (Courtney et al. 1980; Barker et al. 1996).

Ventilation is to provide more air and dilute the dust. Ventilation not only prevents dust but also reduces dangerous methane content. Ventilation also keeps dust source away before it can migrate to workplaces, improving the intake air steam for workers in the mine (Fred, 2003). In a normal condition, the dust control efficiency reaches up to 60%. However, in a heavy dust pollution environment, the ventilation method is less effective.

Water spray is used to prevent dust in a stage loader, in a dead face, at a conveyor transferring point. The dust control efficiency is not efficient enough in dust control and it consumes a lot of water.

High-pressure water spray: One method to improve spray is to increase the water pressure. Dust control with high-pressure water spray is applied in a longwall face, in a roadway. High-pressure water spray is mounted on the shearer drum and installed in the workplaces. Sprays with an operating water flow rate of between 6 to 12 L/min and operating pressure of between 1,6 and 2,2MPa give 70% dust reduction.

Application of high-water pressures ejector system for dust control

In Khe Cham, Ha Lam and Mao Khe mine in Quang Ninh province, high pressure water ejector systems with two types of the nozzle (full-cone and flat nozzle) have been selected and tested to control dust in a roadway and at a stage loader, at conveyor belts, during longwall mining.

Water ejector system is simple and flexible device that generates vacuum using high pressure water jet, sucking the airborne dust and discharging it into water jets with compressed air. The atmosphere which contains airborne dust is suppressed by the small water drops in the water jet.

The effectiveness of dust elimination using water spraying results from the quality of sprayed water drops. The smaller the droplets of water, the greater efficiency in capturing the dust particles, which results from the fact that the surface of dust absorption increases, and thus the total area of all droplets of the spray stream, without changing their total volume (Douglas et al. 2007; Dominik 2019; Wu et al., 2021).

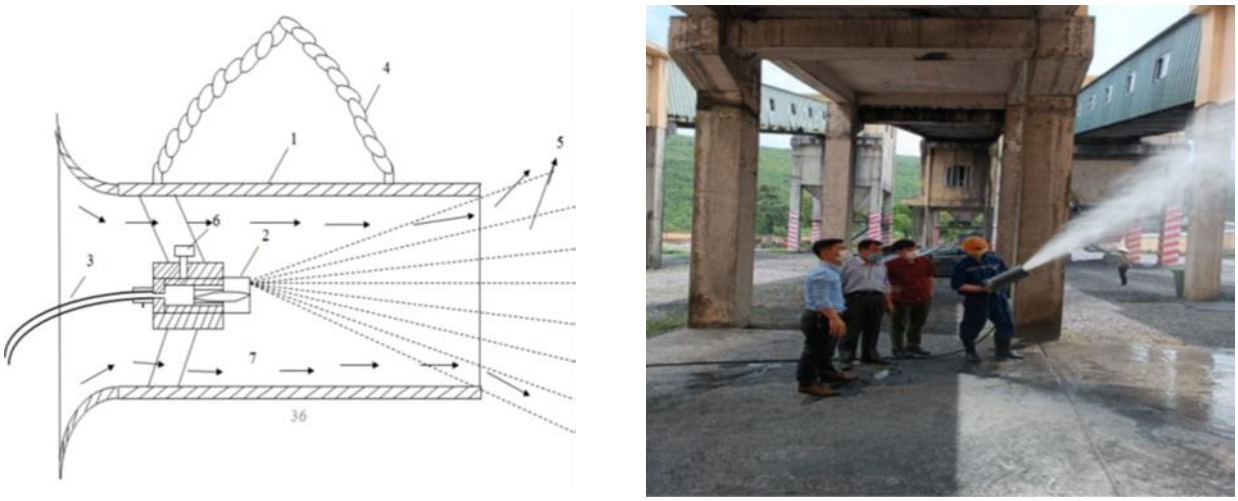
The dust concentration measurements are taken at some positions in the longwall and at the miner's workplace using the personal gravimetric dust meters SKC EPAM-5000. Dust concentration determination which is the essential feature of a sampling system, comprises of a filter (on which the sample is collected) and a pump for drawing the air through the filter.

High water pressures ejector system with a full-cone nozzle

Design of the high-water pressures ejector system with a full-cone nozzle

High water pressures ejector system with a full-cone nozzle is used to control dust in a longwall face, in a roadway and at a stage loader. Although high-pressure spray can improve the efficiency of dust fall, high-pressure spray will cause dust disturbance, resulting in secondary dust. Therefore, nozzle installation location, spray pressure, and flow rate need to be adjusted (Wu et al., 2021).

The ejector system is composed of an airflow collector, a full-cone nozzle KP-40 with spray angle 40^o at operating pressure of between 1,6 and 2 MPa. High-water pressures ejector system with full-cone nozzle is shown in Figure1.



a) b)

Fig. 1. Schematic diagram and test of the high-pressure water system with a full-cone nozzle
(a) System of the high-pressure water ejector:
1. Airflow collector; 2. Spray nozzles KP 1-6-40; 3. Water pipe with pressure rated up to 4 MPa;
4. Hanging rope; 5. Mist beam; 6. Nozzle fixing screw; 7. Nozzle holder.
(b) Testing of the water jet ejector system operating at high pressure at the ground level +75 in Ha Lam mine

Measurement data of conventional performance parameters of the full-cone nozzles KP-40 under different pressures is shown in Table 1.

Table 1: *Measurement data of conventional performance parameters of the full-cone nozzles KP-40 under different pressures*

No	Pressure (MPa)	Flow (dm^3/min)	Spray angle
1	0,5	4,92	40^o
2	1	6,95	
3	1,5	8,52	
4	2	9,84	
5	2,5	11	

It is determined that the high-pressure ejector system with full-cone nozzles KP-40, spray angle 40^o, operating at 1,5 MPa, and a flow rate of 8,52 L/min has the best effect on the dust reduction in the coal mine. The effective range of the ejector system is 0,76 m.

Application of the high-water pressures ejector system with a full-cone nozzle to control dust

High pressure water ejector system with a full cone nozzle is used for controlling the dust during longwall mining in Khe Cham, Ha Lam Coal mine. Dust control results of the ejector system are shown in Tables 2 and 3.

Table 2. *Results of dust control using the high-pressure water ejector system with a full cone nozzle during longwall mining in Khe Cham Coal mine*

Mining operations		Sampling positions	Sample numbers	Average dust concen-tration mg/m^3
Drilling	Control off	2 m away from the face	16	395
	Control on	2 m away from the face	11	10
Blasting	Control off	3 m away from the face	32	306,7
	Control on	3 m away from the face	12	30
Loading	Control off	5 m away from the face	16	325,6
	Control on	5 m away from the face	20	30

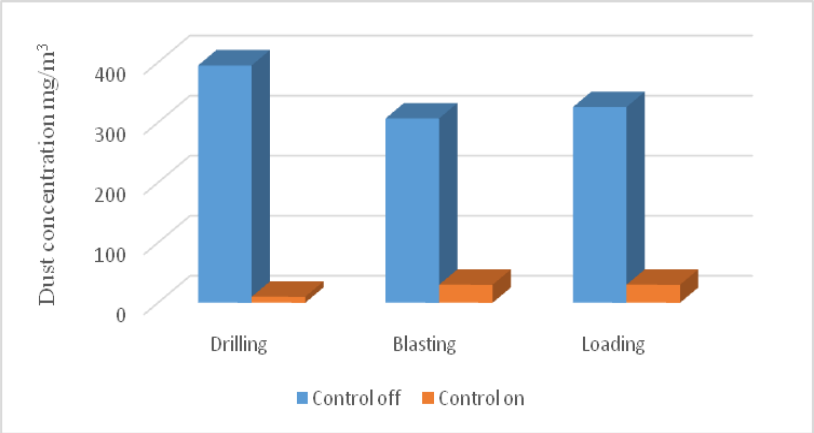


Fig. 2. Graph of dust control results by a high-pressure water ejector system with a full cone nozzle at Khe Cham coal mine

As can be seen in Figure 2, the measurements taken using the water ejector system show that the effectiveness of reduction of dust concentration is over 90% in Khe Cham Coal mine.

The high-pressure water ejector system with a full cone nozzle is used in Ha Lam Coal mine to control dust at the ground level +75, preparation face -300, seam 7, area I in Ha Lam Coal mine. Dust control results of the ejector system are shown in Table 3.

Table 3. *Results of dust control using the high-pressure water ejector system with full cone nozzle in Ha Lam Coal mine*

	Dust type	Dust exposure Limits mg/m^3	Control off		Control on	
			Date	Average dust concentration mg/m^3	Date	Average dust concentration mg/m^3
Ground level+75 Preparation face -300, seam 7, area I	Coal	10	19/04/2022	115	19/04/2022	25,33
	Rock	2	20/04/2022	87 After 30' blast	20/04/2022	10,66

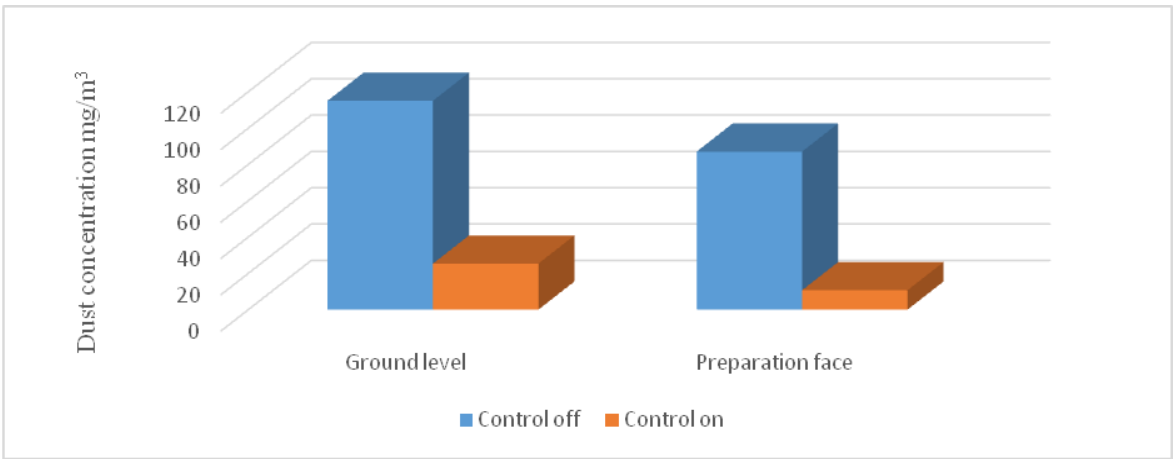


Fig. 3. Dust control results using a high-pressure water ejector system with a full cone nozzle in Ha Lam coal mine

The results of dust control at the ground level +75, preparation face -300, seam 7, area I, are shown on Figure 3. The measurements taken when using the water ejector system show that the effectiveness of reduction of dust concentration at the ground level +75 is 77%, while the effectiveness of reduction of dust concentration at the preparation face reaches up to 88%.

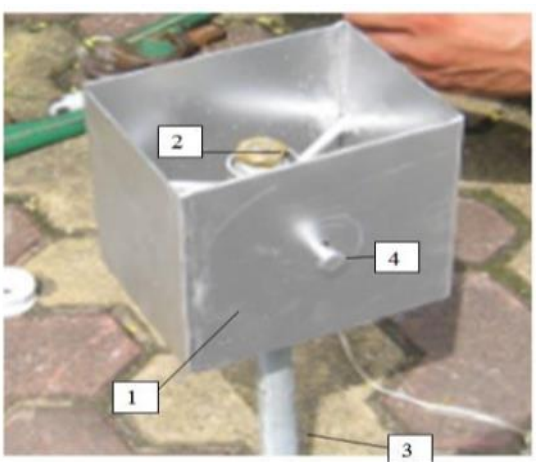
The high pressure water ejector system, at the highest possible effectiveness of the spraying system, consumes about 2÷3 times less water than in the case of normal water spraying. In addition, the temperature at the face could decrease by 1÷5 ^oC, improving working conditions for workers.

High water pressures ejector system with a flat nozzle

Design of high-water pressures ejector system with a flat nozzle

The ejector system is composed of an airflow collector, a flat nozzle CE-120 with spray angle 120^o at an operating pressure of between 0,5 and 2,5 MPa.

High water pressures ejector system with a flat nozzle is shown in Figure 4.



a)

b)

Fig.. 4. Design and test of the high-pressure water system with a flat nozzle
(a) System of the high-pressure water ejector system
1. Airflow collector; 2. Spray nozzles CE – 1,3-120; 3. Water pipe D =21 mm with pressure rated up to 3 MPa; 4. Nozzle fixing screw.
(b) Testing of the water ejector system operating at high pressure

Table 4. *Measurement data of conventional performance parameters of the flat nozzles CE-120 under different pressures*

N	Pressure (MPa)	Flow (dm^3/min)	Spray angle
1	0,5	2,9	120°
2	1	3,8	
3	1,5	5	
4	2	5,8	
5	2,5	6,5	

It is determined that the high-pressure ejector system with flat nozzles CE-120, spray angle 120°, operating at 1 MPa and a flow rate of 3,8 L/min has the best effect on the dust reduction in the coal mine. The effective range of the ejector system is 1,3 m.

Application of the high-water pressures ejector system with a flat nozzle to control dust

High-water pressures ejector system with a flat nozzle is typically used for coal wetting along the conveyor belts, in ventilation roadways and connecting roadways. Dust control results of the ejector system are shown in Table 5.

Table 5. *Results of dust control with the high-pressure water ejector system using a flat nozzle in Mao Khe Coal mine*

Sampling position	The ejector system	Dust concentration			
		Control off		Control on	
		Date	Average dust concentration mg/m^3	Date	Average dust concentration mg/m^3
Connecting roadway -25	#1	09/05/2022	115,5	10/05/2022	45,3
Dropping-25	#2	09/05/2022	109,5	10/05/2022	20,8
Connecting roadway -80	#3	09/05/2022	108	10/05/2022	8,77
Connecting roadway -80	#4	09/05/2022	106,6	10/05/2022	4,43
Connecting roadway -80	#5	09/05/2022	105	10/05/2022	2,6
Connecting roadway -80	#6	09/05/2022	103,8	10/05/2022	2,07
Connecting roadway -80	#7	09/05/2022	100	10/05/2022	1,93
Connecting roadway -80	#8	09/05/2022	98,2	10/05/2022	1,73
Connecting roadway -80	#9	09/05/2022	94,8	10/05/2022	1,67

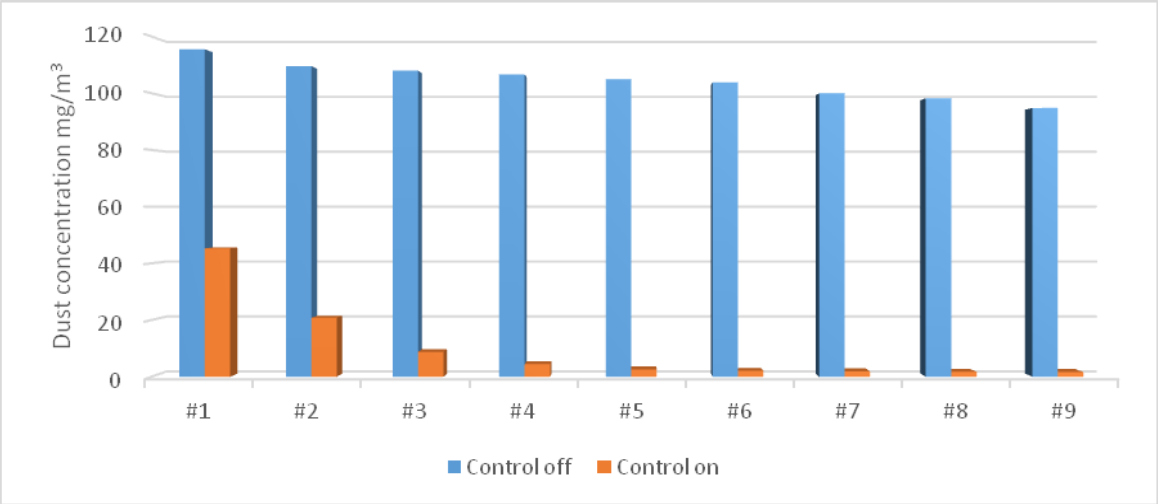


Fig. 5. Dust control results using high-pressure water ejector system with a flat nozzle in Mao Khe coal mine

As shown in Figure 5, the amounts of dust generated from the belt conveyors of the main shaft and the transportation roadways range from 94,8 ÷ 115,5 mg/m^3, while after applying the high-pressure water ejector system with a flat nozzle, the amounts of dust are reduced to 1,6 ÷ 46,5 mg/m^3; the dust control effects are up to 59,7 ÷ 98 %. Moreover, the high-pressure water ejector system consumes about 2 ÷ 3 times less water when compared to normal water spraying.

Based on the results of testing in Khe Cham, Ha Lam, Mao Khe mine, the high-pressure water ejector system could be applied widely for other underground mines in Quang Ninh province to control dust during longwall mining and improve working conditions.

Conclusion

Dust emissions in the air can adversely affect the health of mine workers and lead to lung disease, asthma, irritation to the eyes. Mining dust is the result of extraction, maintenance or processing activities. Therefore, selecting the appropriate system is an important long-term decision. Not only do dust control system clear the air, but they also improve dust reduction efficiency, help ensure safe operations and reduce the amount of reactive maintenance that machines need.

The high-pressure water ejector systems, which were selected and designed to control the dust during longwall mining in Quang Ninh, reduce the amount of dust generated around the workplace to a concentration that does not endanger the exploitation and does not exceed the safety level of dust concentrations.

The high-pressure water ejector system achieves about 60 ÷ 98% effective dust reduction. Moreover, in case of the ejector system, water consumption is about 2 ÷ 3 times less than in the case of normal water spraying. When the high-pressure water ejector system is applied, it does not humidify roadways, equipment and working places.

The ejector system has a simple design, minimal maintenance and durable construction. It is feasible to manufacture it with available materials and equipment in Vietnam.

Conflict of Interest:
The authors declare that they have no conflict of interest.

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