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DUST CONTROL WITH USE OF AIR-WATER SPRAYING SYSTEM

REDUKCJA ZAPYLENIA POWIETRZA Z WYKORZYSTANIEM ZRASZANIA POWIETRZNO-WODNEGO

Results from testing the dust control efficiency, when using air-water spraying system in comparison to the typical water spraying system are presented in the paper. The tests were carried out in conditions of longwall mining and at the places of run-of-mine transportation.

Also the results of stand tests of different types of nozzles both for air-water and for water spaying systems carried out at KOMAG's laboratory and in real conditions are presented. The benefits resulting from air-water spraying system have been determined.

Keywords: airborne dust control, airborne dust, spraying system, air-and-water spraying system, natural hazards.

W artykule przedstawiono wyniki badań skuteczności redukcji zapylenia z wykorzystaniem zraszania powietrzno-wodnego w odniesieniu do zraszania wodnego. Badania przeprowadzono w warunkach technologii eksploatacji węgla systemem ścianowym oraz w miejscu odstawy urobku.

Zaprezentowano również wyniki badań stanowiskowych różnego typu dysz zraszających, zarówno dla zraszania powietrzno-wodnego, jak i wodnego, które przeprowadzono w laboratorium ITG KOMAG oraz w warunkach rzeczywistych. Określono efekty wynikające ze stosowania zraszania powietrzno-wodnego.

Słowa kluczowe: redukcja zapylenia, zapylenie, zraszanie, zraszanie powietrzno-wodne, zagrożenia naturalne

1. Introduction

Airborne dust in mine exposes workers to the danger of pneumoconiosis as well as it increases the hazard of coal dust explosion and its propagation. According to the regulations, it is necessary to undertake the measures to protect the deposited coal dust against ignition, when dust concentration exceeds 30 g/m^3.

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According to the report (Konopko, 2010), exposition of respiratory system of employees to dusty air in mines results in 400÷500 new cases of pneumoconiosis each year (Lebecki, 2004; Pieczora, 2009; Rojek, 2010), while the time of illness accumulation is from 5 to 10 years depending on intensity of exposition of respiratory system to dust respirable fraction (Bradecki & Dubiński, 2005; Cichowski 2000). It is estimated that in the next years the number of pneumoconiosis cases will increase. Current methods used to control airborne dust in mines, including the methods, which use the spraying systems and ventilation, do not give the expected result, i.e. reduction of dust level below the highest permissible concentration. The spraying method which use rotating spraying curtain (RAC) installed in cutting drums manufactured by Krummenauer (Mielniczuk et al., 2000) was one of the methods, which led to reduction of airborne dust concentration below the highest permissible level. Then the airborne dust concentration was at the level at which the personnel could work without equipment protecting the respiratory system. However, consumption of spraying water was about 400 l/min, so it exceeded water consumption of a typical shearer spraying system.

Dust control and spraying are the main methods, which are used to control airborne dust (Branny & Filipek, 2008). Dry and wet dust controllers with the exhaust fan fixed to the roadheader or in its vicinity, are mainly used in roadway faces. Spraying systems are used in longwall panels and roadway faces as a part of shearers or roadheaders equipments or as an independent installation fixed to the roadway support (Cecala & Jayaraman, 2003). Spraying on crushers, transferring points of conveyors and in roadways in a form of spraying curtains is also used.

Due to the problems caused by excessive amount of water in a roadway resulting from use of water spraying systems, air-and-water spraying systems are used more often. They have good properties as regards extinguishing of methane ignition and dilution of accumulated methane as well as they consume less volume of water. Higher effectiveness of dust control is reached due to atomization of water to the smaller particles than in the case of traditional water spraying systems (Pieczora et al., 2009). Such solutions do not require use of pump increasing the pressure because the required water pressure is usually lower that can be found in fire fighting pipelines.

Research, development and implementation work as regards use of air-and-water spraying to reduce airborne dust concentration has been carried out at the KOMAG Institute of Mining Technology for many years. Designing and implementation of spraying installations, which use air-and-water spraying system and which are used in longwall shearers (Joint publication, 1985), in roadheaders (Libera et al., 2010), at transferring points of conveyors (Bałaga et al., 2008) as well as in spraying curtains designed for control of airborne dust in roadways (Bałaga et al., 2010), are the result of this work. At the same time air-and-water spraying nozzles are designed and tested (Prostański, 2008). The tests are carried out in a virtual environment (IniTech Project, 2011), at stands with models of objects (Prostański et al., 2008) and on real objects (Bałaga et al., 2010; Prostański & Rojek, 2006, Prostański et al., 2008).

2. Tests of spraying nozzles

A series of types of air-and-water spraying nozzles (Fig. 1) were designed and manufactured at the KOMAG Institute of Mining Technology. The nozzles have openings, which deliver water and compressed air to the mixing chamber, from which the water atomized with compressed air, is ejected (Prostański 2008).

Fig. 1. STK air-and-water spraying nozzles (Pieczora et al., 2009)

The following assumptions were made during development of a new solution of the spraying nozzle:

- small amount of consumed water, which is below 1 dm^3/min,
- reinforced structure resistant to impacts,
- supply pressure below 1 MPa,
- high diameter of outlet opening,
- simple design,
- reliable and easy to replace seals,
- resistance to the nozzle clogging,
- wide range of spraying.

However, delivery of about 100 dm^3/min of compressed air and a supply with water and compressed air under pressure of about 0.5 MPa is required to meet these assumptions. In the result of mixing of both media a sudden burst of water, atomized by air, half volume of which has drops of diameter not exceeding ten or so micrometers (Fig. 2), takes place. Air-and-water nozzle produces about 1000 times more drops than water nozzle and the surface of these drops is about million times greater (Pieczora et al., 2009). According to the simulation tests, outflow speed of spraying stream near the nozzle outlet is even up to 900 m/s (INERG, 2010), what proves increased atomization of water and increase of drops kinetic energy, which have an impact on improvement of effectiveness of elimination of dust particles from polluted air (Pieczora et al., 2009; Prostański, 2008).

The resulted parameters of spraying stream cause that design of STK air-and-water spraying nozzle gave better chance to combine sprayed water drops with dust particles what means better reduction of airborne dust concentration than in the case of water nozzles. Observations as regards testing the effectiveness of spraying nozzles (Prostański 2008; Pieczora 2009; Rojek 2011) are consistent with the results of research work carried out in many scientific centres (Changi et al., 1996; Karowiec, 1984; Joint publication, 1985).

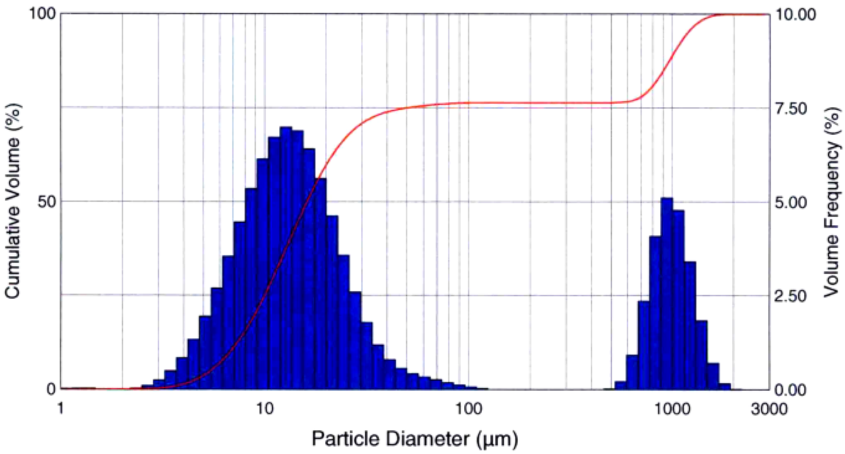

Fig. 2. Frictional distribution of drops atomized by StK-2D nozzle (Prostański, 2008)

Research work on spraying nozzles available on the market as well as own solutions (INERG, 2010; Pieczora, 2009; Pieczora et al., 2009; Prostański, 2008, 2011a; Prostański & Rojek, 2006; Prostański et al., 2008; Rojek 2011) is carried out to assess spraying effectiveness in the aspect of reduction of dust concentration. "Model" coal dust, in which 90% of particles do not exceed 10 µm, is used for testing.

The effectiveness of spraying is understood as the ratio of airborne dust concentration, when no spraying is used to the dust concentration when air-and-water spraying is used. The effectiveness of airborne dust control with use of air-and-water spraying system has been compared with the effectiveness of airborne dust control when use of water spraying system was used.

The tests (Pieczora, 2009; Rojek, 2011) were carried out in test stand equipped with dust feeder, system for dust control, supply system of spraying chamber and the measuring system. The effectiveness of dust control with use of G-243 nozzles supplied with water (Pieczora, 2009) and STK nozzles supplied with water and air (Rojek, 2011) was assessed in two independent tests. The effectiveness of spraying as regards reduction of airborne dust concentration was assessed by measuring a difference between the mass of dust fed into the measuring tunnel and the mass of dust deposited on the filter. The calculated effectiveness of reduction of total airborne dust concentration with use of water spraying system was 70÷95% (Fig. 3). The nozzles were supplied with water of pressure 1÷9 MPa, and water consumption in the spraying system, which consisted of four nozzles, varied from 1 to 38 dm3/min.

The calculated effectiveness of air-and-water spraying as regards reduction of total dust concentration for air and water pressure of 0.3÷1.3 MPa, at water consumption in the range of 3÷8 dm^3/min and for the battery of four STK spraying nozzles was 61÷94%. This effectiveness was 67÷77% for 0.5 MPa ±10% (Fig. 3). The analysis showed that effectiveness of reduction of total dust concentration with use of air-and-water spraying is comparable with the effectiveness of water spraying. In the case of air-and-water spraying system water consumption, at the highest possible effectiveness of spraying system, is about five times smaller than in the case of water spraying (Rojek, 2011).

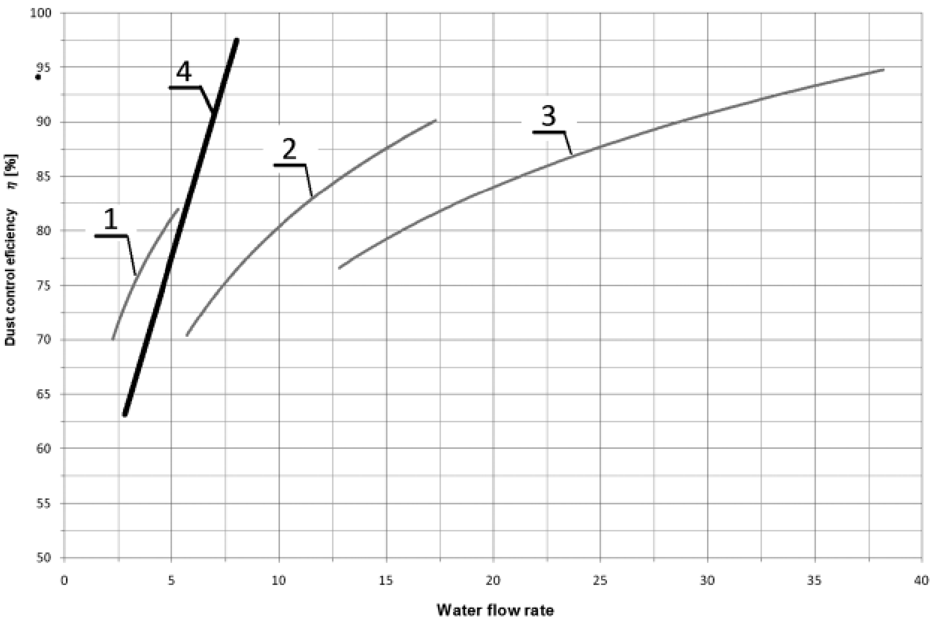

Fig. 3. Characteristics of effectiveness of dust control in a function of water flow intensity, 1,2,3 – water nozzles, 4 – air-and-water nozzle (Rojek, 2011)

Basing on gained experience the test stand has been modernized by use of CIP-10 gravimetric dust measuring devices for the measurement of respirable fraction and total fraction of dust at the outlet of the spraying chamber (Rojek, 2011). Optical dust measuring devices, which enabled continuous recording of changes of dust concentration in time, were also installed in the stand. The measurements taken with use of air-and-water spraying system showed that effectiveness of reduction of respirable dust concentration was 67÷69% (Fig. 4), while the effectiveness of reduction of total dust concentration was in the range 72÷85,5% (Fig. 5). Analysis of tests results showed that effectiveness of dust control depended on supply parameters of spraying system. Water supply pressure was of about 0.55 MPa, while air supply pressure was in the range 0.5÷0.65 MPa.

The tests enabled comparing the effectiveness of reduction of respirable and total dust concentration when using the water spraying and air-and-water spraying in the same conditions. From the tests it results that for reduction of total dust concentration both types of spraying installation show similar effectiveness. However, water spraying requires about five times more water than air-and-water spraying system. As regards reduction of respirable dust concentration only the tests with use of air-and-water spraying system were carried out. The effectiveness of control of dust respirable fraction varied from 67% to 68%.

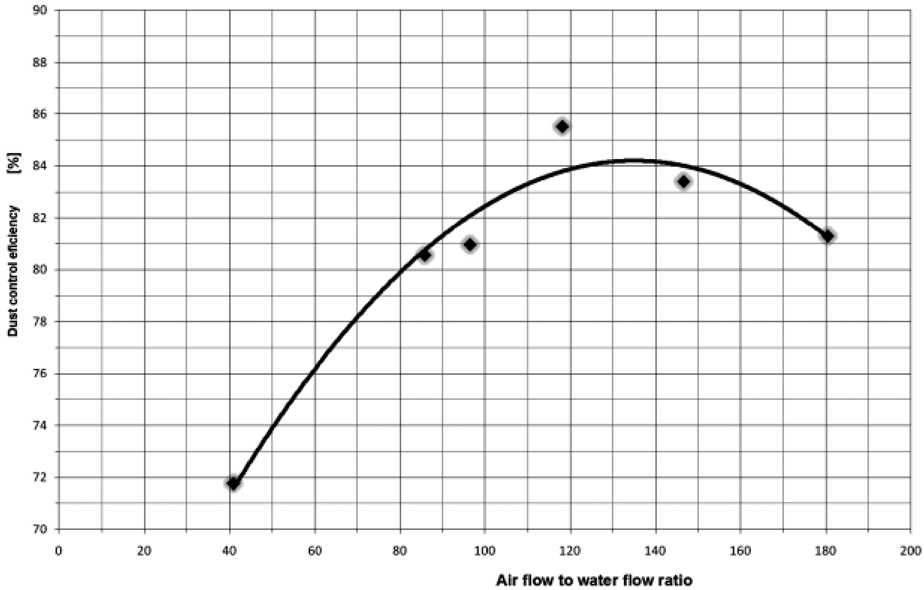

Fig. 4. Effectiveness of dust control in a function of air flow intensity and water flow intensity ratio – total dust (Rojek, 2011)

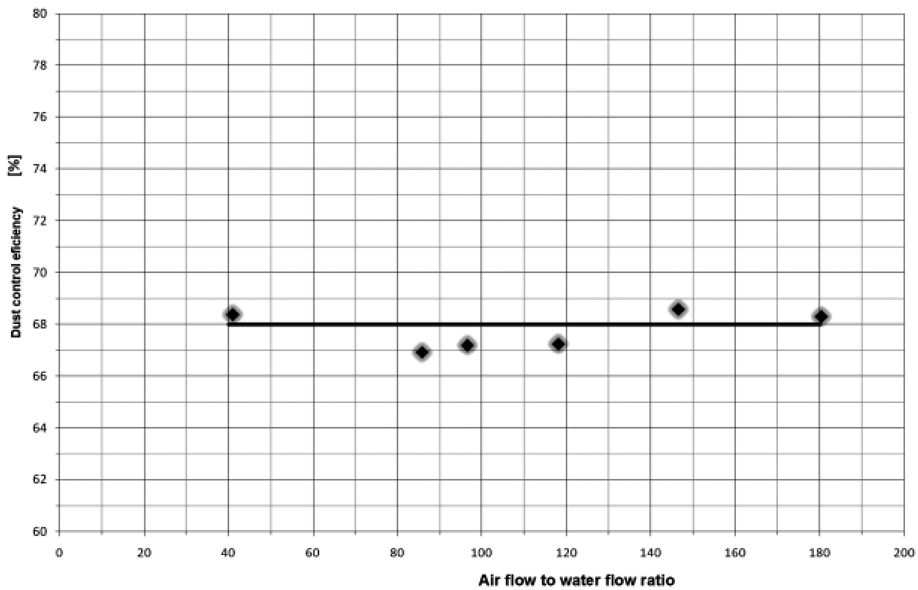

Fig. 5. Effectiveness of dust control in a function of air flow intensity and water flow intensity ratio – respirable dust (Rojek, 2011)

3. Tests in real conditions

The tests in operational conditions were carried out to determine the impact of spraying installations on a reduction of dust concentration.

The tests were carried out in the longwall panels equipped with KSW-460NE longwall shearer with air-and-water spraying installation using the CIP-10 personal dust measuring devices (Pieczora et al., 2008, (Prostański, Rojek, 2006). It was proved that a difference between dust concentration at the longwall inflow and outflow varies from *5.28* to 7.36 mg/m^3 as regards respirable fraction and from 33.79 to 44.14 mg/m^3 as regards total fraction. The tests showed only what amount of dust concentration, generated mainly by the shearer, can be found at the longwall outflow when using air-and water spraying system.

During the other tests (Bałaga et al., 2011), which were carried out in a longwall panel with KSW-880EU longwall shearer using air-and-water spraying system with STK-Z nozzles and G-243 nozzles installed in a cutting drum, the effectiveness of dust control when using water spraying system was compared with the effectiveness of dust control when using air-and-water spraying system (Fig. 6).

Dust concentration measurements were taken at the following three places in the longwall panel: longwall inlet, stand of shearer's operator and longwall outlet. The measurements were taken during mining in the direction opposite to the airflow.

No respirable dust was detected at the longwall inlet and a concentration of total dust there was equal to 0.05 mg/m^3. Respirable dust of concentration equal to 0.08 mg/m^3 and total dust of concentration equal to 11.85 mg/m^3 were found at the longwall outlet when air-and-water spraying installation was used, and total dust concentration equal to 11.78 mg/m^3 was found there when

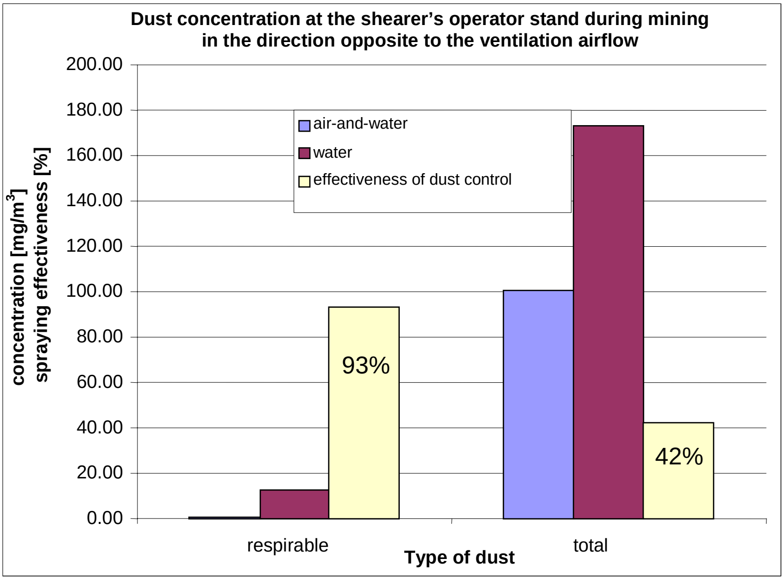

Fig. 6. Comparison of effectiveness of dust control with use of air-and-water and water spraying systems (Bałaga et al., 2011)

water spraying was used. Total dust concentration at the longwall outlet was similar irrespective of the type of used spraying. Respirable dust concentration equal to 0.89 mg/m^3 and total dust concentration equal to 99 mg/m^3 were measured at the shearer's operator stand when air-and-water spraying was used, and respirable dust concentration equal to 12,51 mg/m^3 and total dust concentration equal to 173 mg/m^3 were measured there in the case of water spraying.

The above tests proved that effectiveness of dust control in the case of using the air-and-water spraying system was higher, i.e. by 42% for total dust and by *93%* for respirable dust, than in the case of using the water spraying system. During mining with the shearer having air-and-water spraying system respirable dust concentration was below the highest permissible concentration equal to 2 mg/m^3 while in the case of water spraying system the permissible concentration of respirable dust was exceeded by more than six times and it was fourteen times higher than in the case of using the air-and-water spraying system (Fig. 6).

The next tests (KOMAG, 2011) were carried out on another KSW-880EU shearer according to the same methodology as in the previous tests (Bałaga et al., 2011; Prostański, 2011b). The longwall shearer was equipped with air-and-water STK-Z nozzles and G-243 water nozzles. Effectiveness of dust control between using of water spraying system and using of air-and-water spraying system was compared.

Air-and-water spraying system in the shearer arm had only three active air-and-water nozzles on the right side of the shearer and two active air-and-water nozzles on the left side of the shearer from eleven nozzles installed on each arm. The measurements of dust concentration in both mining directions were recorded. Results of the measurements are presented in Tables 1 and 2.

TABLE 1

Measurements of dust concentration taken during mining with shearer in the direction opposite to the ventilation airflow

Type of spraying/effectiveness	**Air-and-water**	**Water**	**Effectiveness of air-and-water spraying [%]**
Shearer's operator stand			
Respirable dust [mg/m^3]	20	25	20
Total dust [mg/m^3]	713	1079	34
Longwall outlet			
Respirable dust [mg/m^3]	10	15	33
Total dust [mg/m^3]	34	75	55

TABLE 2

Measurements of dust concentration taken during mining with shearer in the direction of ventilation airflow

Type of spraying/effectiveness	**Air-and-water**	**Water**	**Effectiveness of air-and-water spraying [%]**
Shearer's operator stand			
Respirable dust [mg/m^3]	6	16	62
Total dust [mg/m^3]	101	430	77
Longwall outlet			
Respirable dust [mg/m^3]	11	23	52
Total dust [mg/m^3]	26	47	45

As it results from the conducted tests, during shearer mining in the direction opposite to ventilation airflow (Fig. 7), with use of air-and-water spraying system, the concentration of respirable dust at the shearer's operator stand was equal to 20 mg/m^3 and the concentration of total dust was there equal to 713 mg/m^3. In the case of water spraying system the concentration of respirable dust was equal to 25 mg/m^3 and the concentration of total dust was equal to 1079 mg/m^3. At the longwall outlet (Fig. 8) during use of air-and-water spraying system the concentration of respirable dust was equal to 10 mg/m^3 and the concentration of total dust was equal to 34 mg/m^3, while during use of water spraying system the concentration of respirable dust was equal to 15 mg/m^3 and the concentration of total dust was equal to 75 mg/m^3.

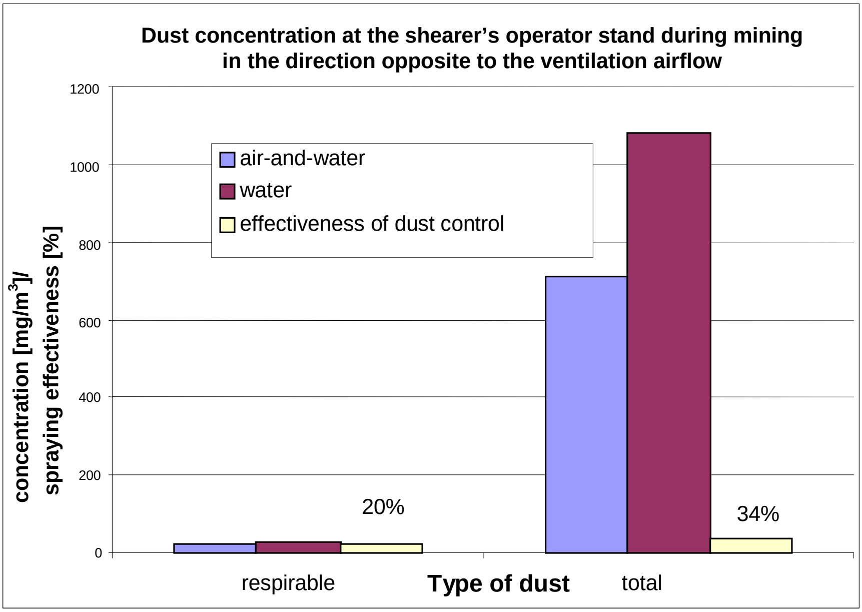

Fig. 7. Comparison of effectiveness of dust control with use of air-and-water and water spraying systems at the shearer operator's stand during mining in the direction opposite to the ventilation airflow

From the above measurements it results that in the case of mining in the direction opposite to the ventilation airflow the effectiveness of dust control with use of air-and-water spraying system at the shearer's operator stand was higher than the effectiveness of dust control with use of water spraying system by 20% for respirable dust and by 34% for total dust. The effectiveness of dust control with use of air-and-water spraying at the longwall outlet was higher than the effectiveness of dust control with use of water spraying system by 33% for respirable dust and by 55% for total dust.

Significantly lower dust concentration was recorded in the case of shearer mining in the direction of ventilation airflow. At the shearer operator's stand when using air-and-water spraying system the respirable dust concentration of 6 mg/m^3 and the total dust concentration of 101 mg/m^3 were recorded, while during operation of water spraying system in the shearer recorded concen-

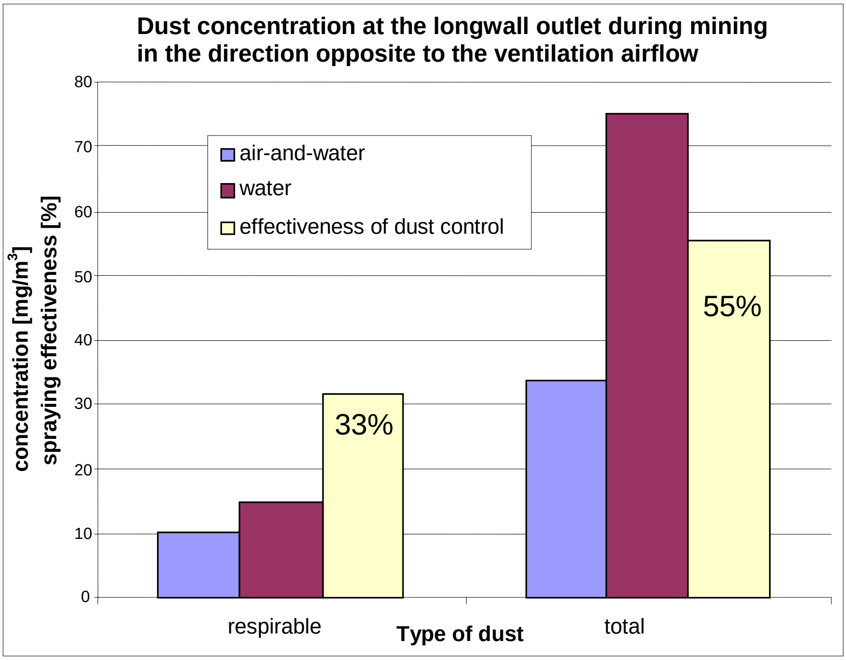

Fig. 8. Comparison of effectiveness of dust control with use of air-and-water and water spraying systems at the longwall outlet during mining in the direction opposite to the ventilation airflow

tration of respirable dust was equal to 16 mg/m^3 and the concentration of total dust was equal to 430 mg/m^3 (Fig. 9). At the longwall outlet the concentration of respirable dust of 11 mg/m^3 and the concentration of total dust of 26 mg/m^3 were recorded when using air-and-water spraying system, while during use of water spraying system the concentration of respirable dust was equal to 23 mg/m^3 and the concentration of total dust was equal to 47 mg/m^3 (Fig. 10).

During shearer mining in the direction of ventilation airflow the effectiveness of dust control at the shearer's operator stand when using air-and-water spraying system was higher than effectiveness of dust control during operation of water spraying system by 62% for respirable dust and by 77% for total dust, while at the longwall outlet it was higher by 52% for respirable dust and by 45% for total dust.

The other tests on effectiveness of dust control with use spraying installation (KOMAG, 2011) were carried out in a vicinity of the conveyor transferring point (Fig. 11). The conveyor transferring point was placed at the roadways crossroad. Run of mine was transported in the direction opposite to the ventilation airflow. Dust concentration was measured in a situation when air-and-water and water spraying installations were used as well as when there was no spraying. The measurements were taken at three points. The first one was at the personnel stand the other two were placed in a distance 5 to 7 m from the conveyor transferring point on height about 60 cm above the belt.

In the result of measurements (Table 3) dust concentration in the specified points was determined and efficiency of dust control at the conveyor transferring point using air-and-water

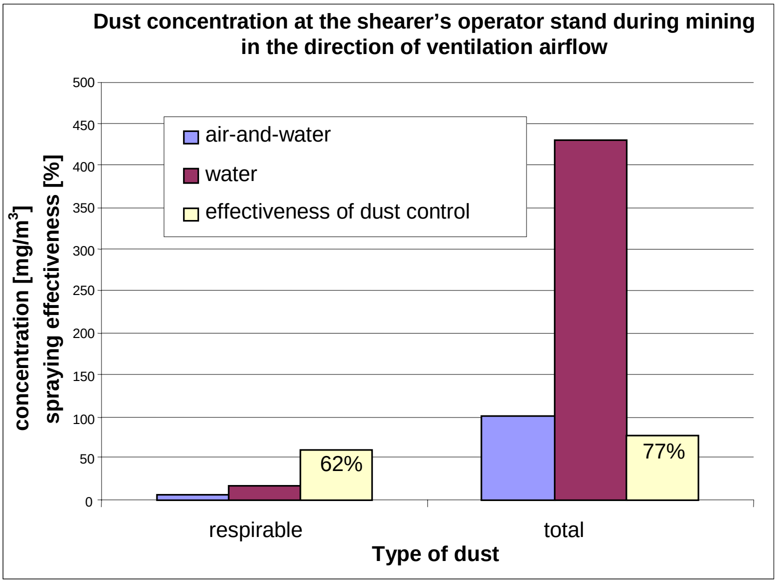

Fig. 9. Comparison of effectiveness of dust control with use of air-and-water and water spraying systems at the shearer operator's stand during mining in the direction of ventilation airflow

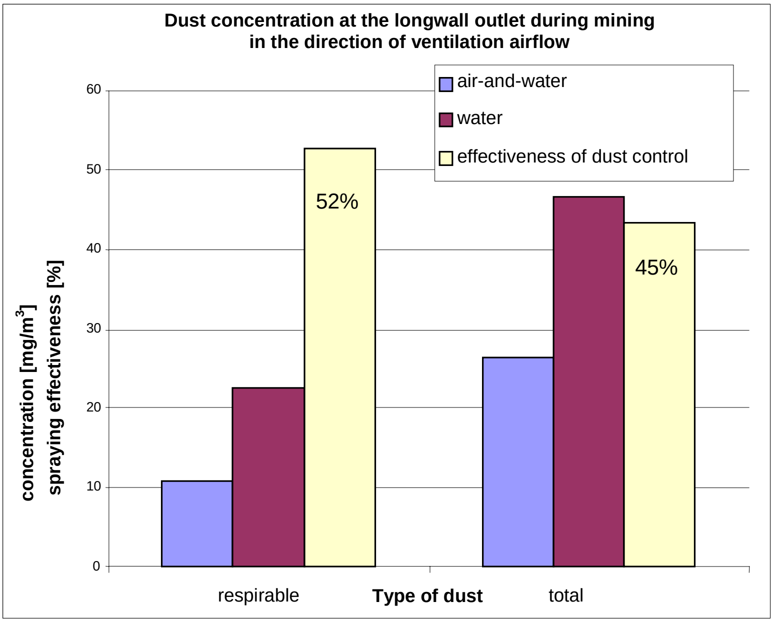

Fig. 10. Comparison of effectiveness of dust control with use of air-and-water and water spraying systems at the longwall outlet during mining in the direction of ventilation airflow

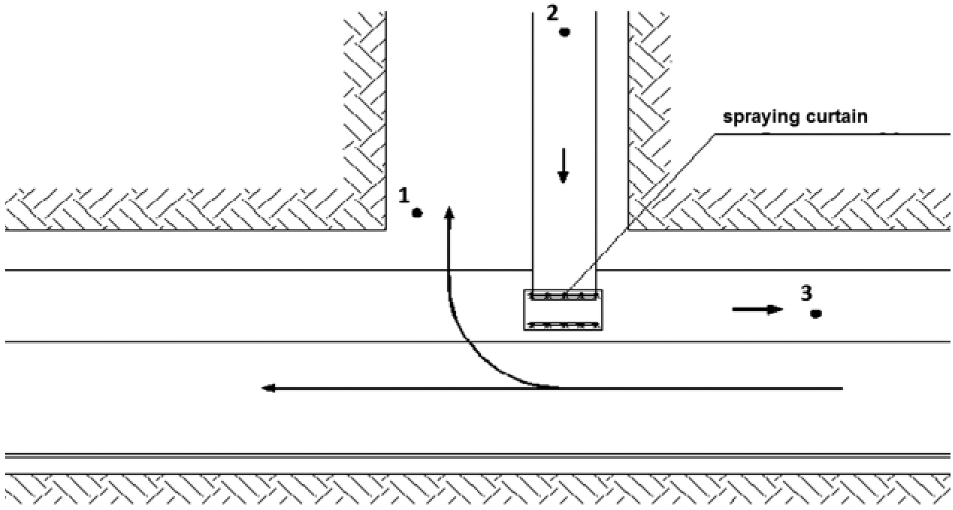

Fig. 11. Arrangement of CIP-10 at the conveyor transferring point at the roadway crossroad

spraying curtain and with use of water spraying pack used so far in the mine was calculated. Also effectiveness of air-and-water spraying installation in relation to water spraying installation was calculated.

When air-and-water spraying curtain was used, the concentration of respirable dust was 0.8 mg/m^3 at the measuring point No. 1 and 1.9 mg/m^3 at the measuring point No. 3. When water spraying installation was used, the concentration of respirable dust at the measuring point No. 1 was 8.3 mg/m^3 and at the measuring point No. 3 was 9.7 mg/m^3. When there was no water spraying, the concentration of respirable dust at the measuring point No. 1 was 8.6 mg/m^3. At the personnel stand – the measuring point No. 1 (Fig. 12), when using air-and-water spraying system, the concentration of respirable dust was reduced to the value 2.5 times lower than MAC, reaching the effectiveness of dust control near 91%. The water spraying system, used so far with the effectiveness of over twenty times lower, enabled to reduce respirable dust concentration only by about 4.4%. Efficiency of total dust control with use of air-and-water spaying system was about 80% and with use of water spraying it was lower and it was equal to 50%.

At the measuring point No. 2 efficiency of total dust control with use of air-and-water spaying system was about 90% in relation to water spraying installation. At the measuring point No. 3 effectiveness of total dust control with use of air-and-water spaying system was 61%, and in the case of water spraying was about 38%. Effectiveness of respirable dust control with use of air-and-water spaying system was about 80% in relation to water spraying system.

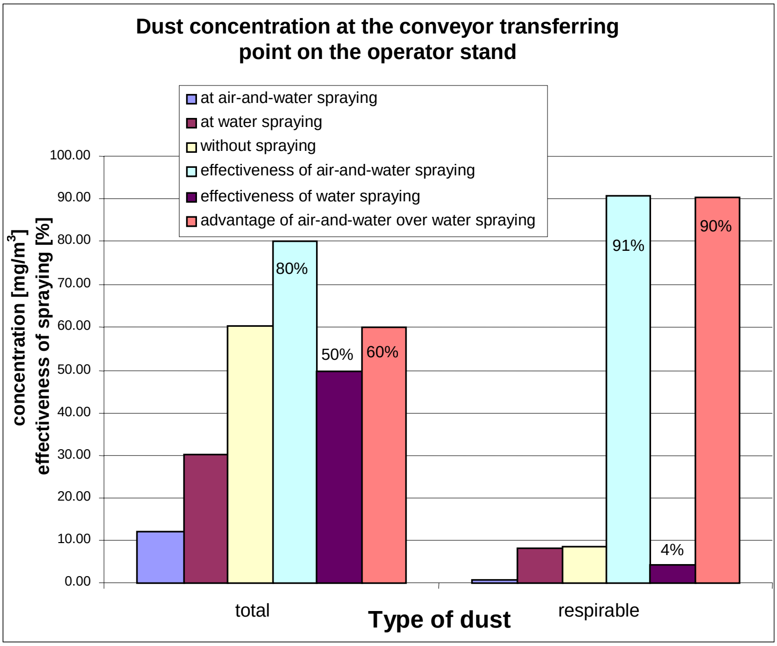

Fig. 12. Comparison of dust control effectiveness with use of air-and-water spraying system and with use of water spraying system at the conveyor transferring point

TABLE 3

Measurements of airborne dust concentration at conveyor transferring point with the ventilation direction opposite to transportation direction

Dust fraction	Type of spraying			Effectiveness of air-and-water spraying to water spraying [%]	Effectiveness of air-and-water spraying [%]	Effectiveness of water spraying [%]
	Air-and-water	Water	Without			
Measuring point No. 1						
Respirable [mg/m^3]	0.8	8.3	8.6	90.3	90.7	4.4
Total [mg/m^3]	12.1	30.3	60.6	60.1	80.0	50.0
Measuring point No. 2						
Respirable [mg/m^3]	-	-	-	-	-	-
Total [mg/m^3]	8.0	22.5	-	89.6	-	-
Measuring point No. 3						
Respirable [mg/m^3]	1.9	9.7		80.0		
Total [mg/m^3]	19.1	30.4	49.5	37.1	61.3	38.5

4. Summary

Research work and designing of air-and-water installations carried out in the KOMAG Institute of Mining Technology resulted in their use on different types of shearers and roadheaders. These installations significantly reduced the risk of methane ignition as well as concentration of airborne dust generated by cutting machines.

Laboratory and industrial tests proved that air-and-water spraying installation is very efficient in dust control. Its effectiveness in dust control in relation to water spraying installation is 42%, as regards total dust control and 93%, as regards respirable dust control in the case of properly operating spraying installation. During shearer mining, when using air-and-water spraying installation respirable dust concentration was below 2 mg/m^3 (average concentration of respirable dust was 0.88 mg/m^3).

Even at 20% of maximal output of the spraying installation it is possible to reduce dust concentration by half, what is the effect of good water atomization.

In the case of mining in a direction opposite to ventilation airflow, efficiency of dust control with use of air-water spraying installation on the operator stand in relation to water spraying system was by 20% higher for the respirable dust and by 34% for total dust. At the longwall outlet efficiency of dust control with use of air-water spraying installation in relation to water spraying system was by 33% higher for the respirable dust and by 55% for total dust.

During shearer mining in a direction to the ventilation airflow, efficiency of dust control with use of air-water spraying installation on the operator stand in relation to water spraying system was by 62% higher for the respirable dust and by 77% for total dust concentration and at longwall outlet it was higher by 52% for the respirable dust and by 45% for total dust.

Tests of air-and-water spraying installation at the conveyor transferring point showed that it is possible to reduce dust concentration by about 90%, while water installation at the same transferring point was significantly less efficient.

The measurements were taken only during dust generation by shearers and conveyors, but the regulations concerning airborne dust concentration at the workplace say about average dust concentration during entire work shift. The measurements had to determine the effectiveness of airborne dust control with use of air-and-water and water spraying systems and to compare both type of spraying, but not to determine average dust concentration during entire work shift. The average dust concentration measured during the shift would be much lower than those reported during tests.

In future it would be reasonable to make airborne dust maps in the mine, which would show primary and secondary dust sources for economic and effective dust control. Then it would be possible to control dust concentration with small consumption of water in relation to traditional systems (Prostański, 2011b).

In the paper only the installations designed in KOMAG were presented. The mines also use other solutions of air-and-water spraying and these solutions should also be tested to determine their effectiveness and their use in the mine system which protects the mine against excessive dust concentration.

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