


2021

The Level of Securing Dust Deposits Against the Possibility of Coal Dust Explosion in the Drilled Dog Headings

Follow this and additional works at: <https://jsm.gig.eu/journal-of-sustainable-mining>

 Part of the [Explosives Engineering Commons](#), [Oil, Gas, and Energy Commons](#), and the [Sustainability Commons](#)

Recommended Citation

Malich, Bogdan; Cybulski, Krzysztof; Wysocka, Malgorzata; Skubacz, Krystian; Michałek, Aneta; and Urban, Paweł (2021) "The Level of Securing Dust Deposits Against the Possibility of Coal Dust Explosion in the Drilled Dog Headings," *Journal of Sustainable Mining*: Vol. 20 : Iss. 1 , Article 4.
Available at: <https://doi.org/10.46873/2300-3960.1039>

This Research Article is brought to you for free and open access by Journal of Sustainable Mining. It has been accepted for inclusion in Journal of Sustainable Mining by an authorized editor of Journal of Sustainable Mining.

The level of securing dust deposits against the possibility of coal dust explosion in the drilled dog headings

Bogdan Malich, Krzysztof Cybulski, Małgorzata Wysocka, Krystian Skubacz, Aneta Michałek*, Paweł Urban

Central Mining Institute, Katowice, Poland

Abstract

The article presents the analysis how the real coal dust explosion hazard occurs at the distance of the initial 200 m of the protective zone maintained along the entire length of driven inclined drift II – face 567 in Polish colliery KWK “BRZESZCZE”, which was used during realization of the project titled *Modelling of the mechanism of explosive coal dust deposition in the vicinity of mined faces in terms of identification, assessment and levelling the possibility of its explosion* financed by the National Centre for Research and Development in Poland. The mine dust level was between 0.014 kg/m³ and 0.193 kg/m³, and the coal dust level between 0.003 kg/m³ and 0.051 kg/m³, at the content of incombustible solids between 62.9% and 96.9%. In the analysed fragment of the mine working there was settled dry and volatile mine dust of transient water content between 0.1% and 3.8%. In a few measurement points (sidewalls, floor, and the dust explosion barrier) it was observed that the content of incombustible solids was lower than required by the regulations (unsecured mine dust), which resulted from the insufficient application of stone dust and increased intensity of dust settlement, especially in the area near the longwall face. Analyses of the fraction distribution of the settled mine dust showed the presence of fine dust, while coarser fractions were found in the places of lowered content of non-combustible solids. The conclusions indicate that it is necessary to modify the currently applied dust-explosion prevention measures, which ought to adjust the amount of stone dust applied in given sections of the safety zone and the stone dust ought to be applied with more diligence.

Keywords: coal dust, coal dust explosions, dust prevention, safety zones

1. Introduction

The consortium composed of: Instytut Techniki Górniczej KOMAG S.A. (KOMAG Institute of Mining Technology, the project leader, Gliwice, Poland), Główny Instytut Górnictwa (Central Mining Institute Katowice, Poland) and Kompania Węglowa S.A. (Katowice, Poland) from November 2012 as a part of the Applied Research Program implement the project “*Modelling of the mechanism of explosive coal dust deposition in the vicinity of mined faces in terms of identification, assessment and levelling the possibility of its explosion*” financed by the National Centre

for Research and Development under the agreement no PBS1/B2/4/2012. The main objective of the project was the development, based on the results of underground and laboratory tests as well as virtual simulations, of a model of the zone securing against coal dust explosion by spraying with air–water aerosol. This solution is intended to improve safety at work by reducing the labour-consumption related to the execution and renewal of these zones, and also increase of their reliability. A detailed analysis of the deposits correlated with mining and geological conditions was required to determine technical and operational parameters of the sprinkling stream which is

Received 23 November 2020; revised 15 February 2021; accepted 18 February 2021.
Available online 26 March 2021

* Corresponding author.
E-mail address: awieczorek@gig.eu (A. Michałek).

<https://doi.org/10.46873/2300-3960.1039>

2300-3960/© Central Mining Institute, Katowice, Poland. This is an open-access article under the CC-BY 4.0 license (<https://creativecommons.org/licenses/by/4.0/>).

necessary for depriving the volatility and explosive properties of dust deposits. The article presents the analysis of results of tests concerning the real threat of explosion of coal dust carried out at the distance of the first 200 m of the safety zone maintained over the entire length of the drilled recognizing inclined drift II (the conveyor roadway of the longwall 128a) – the forehead 567 in the colliery KWK “BRZESZCZE” as well as information about evolution of factors determining the intensity of formation of dust deposits and dust prevention applied [1].

Unpublished reports documenting the research tasks no 3, no 5 and no 8 of the abovementioned project implemented by the Central Mining Institute were used in this paper.

Similar projects were carried out in Australia between 2000 and 2003, however they focused on the application of stone dust as an agent neutralizing coal dust [2–4]. For several years in the USA manual meters can be used to determine the percentage content of incombustible solids in mine dust [5–7] and the amount of coal dust accumulation in excavations [8] in order to obtain the measurement result practically immediately, however they are encumbered with relatively high error, particularly in case of high moisture of the collected dust sample. Nevertheless, in formulating the research methodology applied in the project, it was decided to collect the samples of deposited mine dust manually, according to the requirements of the Polish Standard PN-G-04037 [9], paying particular attention to their representativeness [10]. The Canadian [11] and American [6,12–14] experience was used in determining the real threat of coal dust explosion and the level of securing coal dust against explosion in the examined area.

2. Materials and methods

The research inclined drift II (GPR-2 branch) with a runway of 898 m (during the study) was used in the West part of the seam 401, with an average thickness of 1.5 m and decline of 8°. Shale clay and local sandstone deposited in the seam roof, and the floor contained mainly shale clay. The research inclined drift II has not been classified yet in terms of the threat of coal dust explosion, therefore the rigors class “B” of this threat were applied for it, which required the mine to maintain safety zones and use explosion barriers. The recognizing inclined drift II was located in the field of IV category of methane hazard and was classified to the premises “c” of methane explosion hazard. No rock burst or

radiation hazard occurred in the area subject to the research, and the seam 401 was classified as non-susceptible to outburst gases and rocks. The research inclined drift II was covered with the first degree of water hazard.

Forcing and combined ventilation was used in the research drilled inclined drift II, with the use of a ventube fan ADF-800B-2/3, flexible ventilation pipe with a diameter of 1200 mm and dust collector UO 630-1. The air speed, its capacity and temperature in this excavation were respectively 0.81 m/s, 600 m³/min and above 29.0 °C. The recognizing inclined drift II was drilled with a heading machine AM-50, and output was transported with a scraper conveyor SKAT-80/KJ and belt conveyors PDT-SIGMA 800 and PTG-50/1000. The amount of the daily progress of the forehead was 6 m (average 130 m monthly).

In the drilled research inclined drift II, the safety zones were maintained over the entire length by sprinkling with waterproof stone dust around the excavation, including the lining to the content of at least 80% of non-combustible solids. According to the *Schedule of inspections and renewal of safety zones* developed by dust service of the colliery KWK “BRZESZCZE”, the frequency of renewals of these zones was at least once every 3 days in the amount of no less than 160 kg of stone dust per day, and the frequency of their inspections, according to the requirements of mining regulations, not less than every 30 days. The results of these periodical inspections (data the closest to the date of examination) showed that the statutory requirements have been met and that the content of incombustible solids in coal dust within the safety zone was 82.7%. The size of the intensity of dust settling in this excavation was 9.71 g/m²/day (4.62 g/m³/day) with the content of incombustible solids of 37.5%. The drilled recognizing inclined drift II was secured with stone-dust explosion barriers – four auxiliary located in this gallery and two main located in the testing gallery of the longwall 128 (no 544) and in the testing gallery I (no 564). The dust service of the colliery KWK “BRZESZCZE” carried out inspection of explosion barriers at least every 30 days.

Based on tests carried out in the research inclined drift II during the production process of the colliery as well as laboratory analyses, the coal dust explosion hazard in this excavation was characterized by:

- determination of the size of dustiness with mine dust and coal dust for 10 measurement points evenly distributed over the length of 200 m of the safety zone (independently for the left and right sidewall and floor, as well as jointly for the measurement point),

- determination of the percentage content of incombustible solids as well as hygroscopic and transient water in the deposited mine dust,
- determination of the presence of areas in the excavation with unsecured mine dust,
- determination of the level of securing coal dust in terms of maintaining the requirements concerning safety zones and locations of explosion barriers,
- determination of the size of the fractional distribution of deposited coal dust.

The activities related to the collection of samples of deposited mine dust were performed by the employees of the Department of Dust Hazard Control of the Experimental Mine “BARBARA” of the Central Mining Institute trained based on the research methodology developed under the project and having experience in this field.

In the recognizing inclined drift II, 10 measurement points were set and they were selected to cover the area of the first 200 m of the maintained safety zone at equal distances. The first point was set at a distance of 10 m from the forehead and the rest

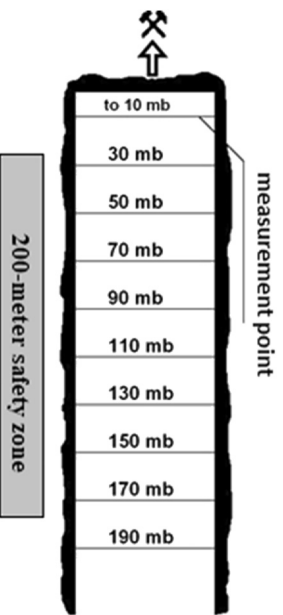


Fig. 1. Location of the measurement points.

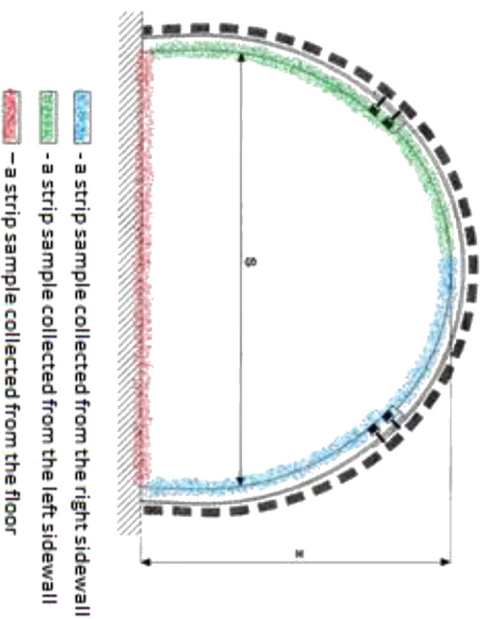


Fig. 2. Chart of samples collection of deposited mine dust with the use of the strip method.

Table 1. Results of laboratory tests of deposited coal dust samples.

Name of the excavation:		Inclined drift II (belt gangway of the longwall 128a) – mine face 567												Date of test:		15 July 2013			
Measurement point	Dustiness, [kg/m ³]								Content, [%]								Cross-section [m ²]		
	Mine dust				Coal dust				Non-combustible solids				Hygroscopic water			Transient water			
	left sidewall	floor	right sidewall	total	left sidewall	Floor	right sidewall	total	left sidewall	floor	right sidewall	average	left sidewall	floor	right sidewall	left sidewall		floor	right sidewall
10 m	0.002	0.011	0.002	0.014	0.001	0.004	0.001	0.005	67.4	63.5	54.3	62.9	0.7	1.0	1.3	0.8	3.8	1.3	13.2
30 m	0.004	0.011	0.007	0.022	<0.001	0.002	0.001	0.003	95.3	81.7	87.1	85.8	0.1	0.4	0.2	0.6	2.5	0.3	12.3
50 m	0.012	0.162	0.005	0.179	0.002	0.048	0.001	0.051	82.0	70.4	78.3	71.4	0.3	0.6	0.5	0.1	1.0	0.6	12.0
70 m	0.001	0.089	0.001	0.091	<0.001	0.028	<0.001	0.029	80.3	68.5	74.0	68.7	0.4	0.6	0.6	0.4	3.1	0.6	13.0
90 m	0.001	0.134	0.006	0.140	<0.001	0.022	<0.001	0.022	78.9	83.7	92.0	84.0	0.4	0.3	0.5	0.6	0.7	0.1	13.2
110 m	0.005	0.181	0.007	0.193	<0.001	0.005	0.001	0.006	93.5	97.4	85.5	96.9	0.1	0.1	0.4	0.2	0.2	0.4	13.4
130 m	0.006	0.118	0.007	0.131	<0.001	0.041	<0.001	0.042	92.5	65.1	96.0	68.0	0.1	0.7	0.2	0.5	1.7	0.3	13.0
150 m	0.003	0.093	0.004	0.100	0.001	0.008	0.001	0.010	74.8	91.3	81.3	90.4	0.5	0.3	0.5	1.1	0.3	1.4	10.5
170 m	0.013	0.108	0.008	0.129	0.003	0.041	0.001	0.045	79.0	61.8	86.8	65.1	0.4	0.6	0.3	0.6	1.1	0.8	11.7
190 m	0.003	0.078	0.001	0.082	0.001	0.002	<0.001	0.003	77.4	97.1	80.2	96.2	0.4	0.2	0.4	0.8	0.2	0.7	11.4
average	0.005	0.098	0.005	0.108	0.001	0.020	0.001	0.022	82.1	78.1	81.6	78.9	0.3	0.5	0.5	0.6	1.5	0.7	12.4

of points were spaced approximately 20 m from each other. The location of the measurement points is shown in Fig. 1.

Due to the fact that in the examined excavation, the deposited mine dust was dry and dispersible, the samples of dust were collected using the strip method which consisted of sweeping the mine dust from the entire excavation (roof, sidewalls, floor) within the area of 20 cm wide at the measurement points. Dust was sieved with a sieve with a mesh size of 3×3 mm to the linen clothing, and then the fines was thoroughly mixed. Afterwards, a sample was collected to a tight container. Dust collected from the left and right sidewall as well as from the floor was treated as separate samples. Each collected sample of mine dust together with its detailed description was delivered to the Department of Dust Hazard Control of the Experimental Mine “BARBARA” of the Central Mining Institute, in order to perform laboratory tests [9]. Measurements of the cross-section of the excavation were taken at each measurement point. The organization of samples collection at the designated measurement points is shown in Fig. 2.

3. Results and discussion

A total of 30 samples of deposited mine dust were collected in the recognizing inclined drift II, 10 from each area: the floor, left sidewall and right sidewall. The results of laboratory samples tests of deposited coal dust collected in particular measurement points are listed in Table 1. Average values which refer to

the entire safety zone of 200 m are also provided for all laboratory tests.

The dustiness with mine dust in particular measurement points and the average within the area of the first 200 m of the safety zone were as follows:

- on the left sidewall – from 0.001 kg/m^3 (70 m and 90 m) to 0.013 kg/m^3 (170 m), average of 0.005 kg/m^3 ,
- on the right sidewall – from 0.001 kg/m^3 (70 m and 190 m) to 0.008 kg/m^3 (170 m), average of 0.005 kg/m^3 ,
- on the floor – from 0.011 kg/m^3 (10 m and 30 m) to 0.181 kg/m^3 (110 m), average of 0.098 kg/m^3 ,
- total (for sidewalls and floor) – from 0.014 kg/m^3 (10 m) to 0.193 kg/m^3 (110 m), average of 0.108 kg/m^3 .

On average, the mine dust deposited on both sidewalls amounted to 0.010 kg/m^3 , and compared to the average amount of the deposited mine dust on the floor (0.098 kg/m^3) it was only 10.2%. Small amounts of dust deposits on sidewalls resulted from the fact that an MM-type net was used as lining on the sidewalls of this excavation, instead of concrete blocks, which prevents accumulation of dust deposits on it.

The dustiness with coal dust in particular measurement points and the average within the area of the first 200 m of the safety zone was:

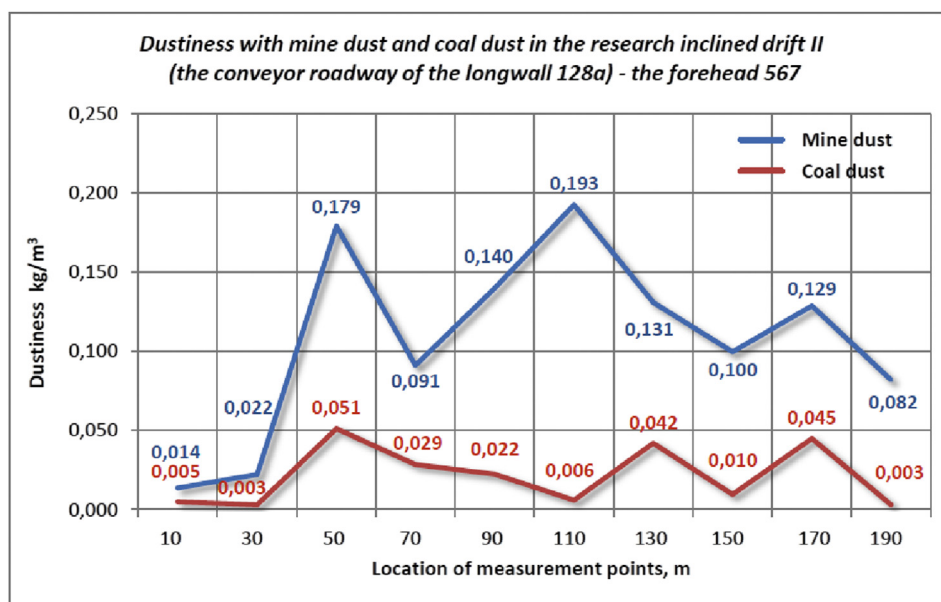


Fig. 3. Dustiness with mine dust and coal dust.

- on the left sidewall – from less than 0.001 kg/m³ (30 m, 70 m, 90 m, 110 m and 130 m) to 0.003 kg/m³ (170 m), average of 0.001 kg/m³,
- on the right sidewall – from less than 0.001 kg/m³ (70 m, 90 m, 130 m and 190 m) to 0.001 kg/m³ (10 m, 30 m, 50 m, 110 m, 150 m and 170 m), average of 0.001 kg/m³,
- on the floor – from 0.002 kg/m³ (30 m and 190 m) to 0.048 kg/m³ (50 m), average of 0.020 kg/m³,
- total (for side walls and floor) – from 0.003 kg/m³ (30 m and 190 m) to 0.051 kg/m³ (50 m), average of 0.022 kg/m³.

On average, the coal dust deposited on both sidewalls amounted to 0.002 kg/m³, and compared to the average amount of the deposited coal dust on the floor (0.020 kg/m³) it was only 10.0%, as in case of mine dust.

The changes in the amount of dustiness with mine dust and coal dust, both for sidewalls and the floor, at particular measurement points in the recognizing inclined drift II are shown in Fig. 3.

The differences in the amount of deposited mine dust resulted mainly from the applied dust explosion prevention in the form of sprinkling with stone dust.

The amount of deposited coal dust did not practically exceed 0.03 kg/m³, except for 3 cases. These cases included the measurement points at the 50 m, 130 m and 170 m, where the amount of this dust was respectively 0.051 kg/m³, 0.042 kg/m³ and 0.045 kg/m³, and it resulted from a low (compared to the rest part of the excavation) content of non-combustible solids (respectively 70.4%, 65.1% and 61.8%).

The content of incombustible solids in the deposited mine dust at particular measurement points and the average within the area of the first 200 m of the safety zone was:

- on the left sidewall from 67.4% (10 m) to 95.3% (30 m), average of 82.1%,
- on the right sidewall from 54.3% (10 m) to 96.0% (130 m), average of 81.6%,
- on the floor from 61.8% (170 m) to 97.4% (110 m), average of 78.1%,
- on average (for both sidewalls and the floor) from 62.9% (10 m) to 96.9% (110 m), average of 78.9%.

Lower (below required by regulations) content of non-combustible solids was found in most measurement points, and mainly it was due to imprecise sprinkling with stone dust. An increased intensity of dust settling within the area of 10-m forehead zone and ineffective dust explosion prevention caused

that the content of incombustible solids in the deposited mine coal significantly differed from the requirements of regulations.

The content of hygroscopic water in the deposited mine dust in particular measurement points and the average within the area of the first 200 m of the safety zone was:

- on the left sidewall from 0.1% (30 m, 110 m and 130 m) to 0.7% (10 m), average of 0.3%,
- on the right sidewall from 0.2% (30 m and 130 m) to 1.3% (10 m), average of 0.5%,
- on the floor from 0.1% (110 m) to 1.0% (10 m), average of 0.5%,

The content of transient water in the deposited mine dust in particular measurement points and the average within the area of the first 200 m of the safety zone was:

- on the left sidewall from 0.1% (30 m) to 1.1% (150 m), average of 0.6%,
- on the right sidewall from 0.1% (90 m) to 1.4% (150 m), average of 0.7%,
- on the floor from 0.2% (110 m and 190 m) to 3.8% (10 m), average of 1.5%,

The content of transient water in the deposited mine dust both on the sidewalls and on the floor in particular measurement points were close to each other and they did not exceed 4.0% (average of 0.9%) and it indicated that the deposited mine dust was dry and volatile over the entire length of the 200-m area of the safety zone subject to the study.

The changes in the content of incombustible solids and transient water in the deposited mine dust, both for sidewalls and floor, in particular measurement points in the research inclined drift II are shown in Fig. 4.

The presence of areas in mining excavations within which coal dust deposits in unsecured mine dust has a big impact on formation of the real coal dust explosion hazard, in the amount which is within its explosion limits (from 50 g/m³ to 1000 g/m³). It is assumed that too high level of risk is when the amount of deposited coal dust exceeds 0.030 kg/m³ of the excavation. Such dust deposits, in case of occurrence of a dynamic factor (blast), have an ability to create dust-air clouds which may initiate an explosion in case of occurrence of a thermal factor (initiator). The abovementioned abilities of mine dust can be neutralized by adding an appropriate amount of incombustible and non-explosive substances, e.g. stone dust or water, and the resulting dust mixtures are characterized by lack of

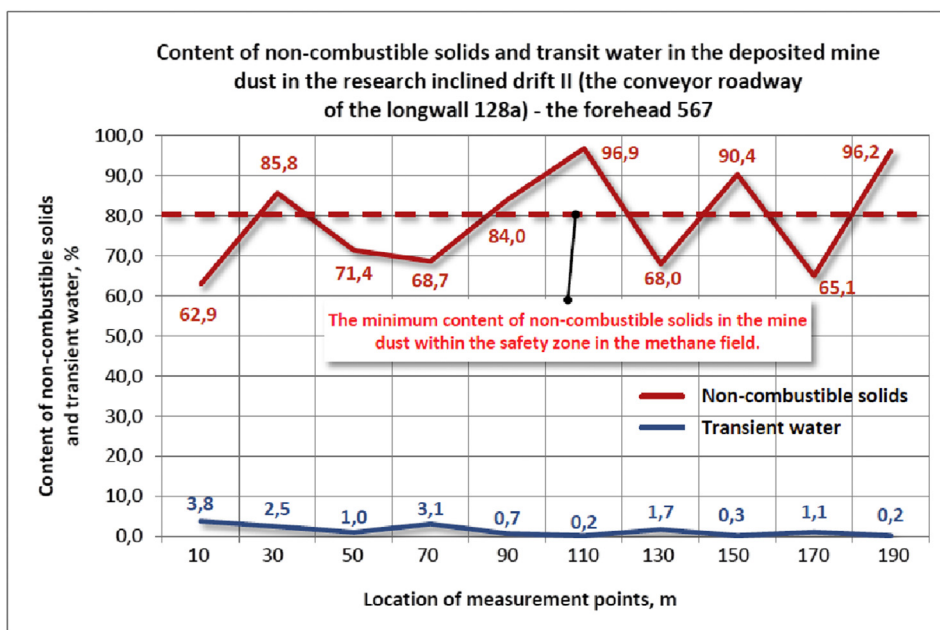


Fig. 4. Content of non-combustible solids and transient water in the deposited mine dust.

explosive capacity. The minimum amount of stone dust or water securing coal dust against the possibility of occurrence and relocation of explosion is specified by mining regulation [15]. In the subject case, the minimum content of non-combustible solids in deposited mine dust should be at least 80%.

Four sections with unsecured mine dust were located within the left sidewall of the excavation (0–20 m, 91–100 m, 151–160 m, 191–200 m) with the content of non-combustible solids from 67.4% to 78.9%, but each time, the amount of coal dust deposited on them did not exceed 0.030 kg/m^3 of the excavation and was below 0.001 to 0.001 kg/m^3 of the excavation.

Two sections with unsecured mine dust were within the right sidewall of the excavation (0–20 m, 0–20 m, 51–80 m) however in both cases, the amount of coal dust deposited on them did not exceed 0.030 kg/m^3 of the excavation and was below 0.001 to 0.001 kg/m^3 of the excavation.

On the floor of the excavation were four sections with unsecured mine dust (0–20 m, 51–80 m, 131–140 m, 171–180 m) with the content of non-combustible solids from 61.8% to 70.4%, and the amount of coal dust deposited on them was in three last cases higher than 0.030 kg/m^3 of the excavation and was respectively 0.048 kg/m^3 , 0.041 kg/m^3 and 0.041 kg/m^3 of the excavation.

The safety zone securing against coal dust explosion is defined as a section of the mining excavation recognized under provisions as safe in terms of a possibility of occurrence and relocation of coal

dust explosion. In the subject case, it is required according to applicable mining regulations [15] to maintain a safety zone within the entire length of the excavation, however the study included the section of the first 200 m. Mining regulations require to sprinkle with stone dust within the safety zone in the entire excavation, including the support. It is assumed that the zone is executed appropriately, if the deposited mine dust is secured against explosion in every place. An inspection of the safety zone is carried out by determining the percentage content of non-combustible solids in the deposited mine dust. According to the Polish Standard [9] the samples of mine dust in the 200-m safety zones should be collected from 3–5 sections spaced 30–50 m from each other along the axis of the excavation, starting from the beginning of the safety zone at a distance of no less than 10 m.

In the subject studies, 10 measurement points were set to increase the accuracy of measurement, while the assessment of the effectiveness of maintaining safety zones was carried out for each measurement point (the weighted mean for the entire excavation) and in accordance with the requirements of the Polish Standard, for the entire safety zone (an average for all measurement points). The evolution of the content of non-combustible solids in the deposited mine dust within the area of the first 200 m of the safety zone, in relation to the requirements of mining regulations (the red horizontal dotted line) are presented in Fig. 4.

Four sections (0–20 m, 51–80 m, 13–140 m, 171–180 m) were found within the area of the first 200 m of the safety zone, where the deposited mine dust was not secured (the requirements of the safety zone were not maintained), and the content of non-combustible solids was from 62.9 to 71.4%. It was calculated, according to the Polish Standard (the average for 10 measurement points), that the content of non-combustible solids at the examined section of the safety zone was 75.9% and it did not meet the requirements of mining regulations.

The irregularities found were removed by dust service of the colliery KWK “BRZESZCZE” by application of additional sprinkling with stone dust and after the next inspection carried out by the employees of the Ventilation Department, it was stated that the security level of mine dust is correct.

According to mining regulations, the location of dust explosion barriers in methane fields should be sprinkled with stone dust up to the content of at least 80% of non-combustible solids.

Four measurement points were located within the dust explosion barrier. The content of incombustible solids in the mine dust deposited in these points was: 68.0%, 90.4%, 65.1% and 96.2% (average of 79.9%) and in two cases it did not meet the requirements of mining regulations. These cases were reported to the dust service of the colliery KWK “BRZESZCZE” and the dust service employees immediately implemented relevant preventive measures.

The collected samples of deposited mine dust were analysed in terms of formation of fractional distributions. The analysis was carried out using a set of sieves: 1 mm, 0.5 mm, 0.2 mm, 0.1 mm, 0.075 mm and 0.063 mm. The past experience concerning the problems of the coal dust explosion hazard indicates that there is a dependency of an increase of coal dust explosiveness with increase of its size distribution. Finer dust fractions characterize with a greater specific surface area from which volatiles that create the mixture of explosive gasses are degassed in contact with the flame of an ignitor.

Table 2. Particle size distribution of deposited coal dust samples.

Inclined drift II									
Measurement point	Fraction [μm]	Particle size distribution, [%]			Measurement point	Fraction [μm]	Particle size distribution, [%]		
		Left sidewall	Floor	Right sidewall			Left sidewall	Floor	Right sidewall
10 m	1000	100.0	100.0	100.0	110 m	1000	100.0	100.0	100.0
	500	92.3	60.2	88.0		500	97.9	98.9	94.4
	200	86.8	31.1	79.1		200	95.7	96.4	89.7
	100	78.0	19.1	70.7		100	89.6	89.3	83.4
	75	73.4	16.1	65.9		75	85.0	82.8	79.0
30 m	63	67.7	14.4	61.1	130 m	63	79.8	77.5	73.2
	1000	100.0	100.0	100.0		1000	100.0	100.0	100.0
	500	98.2	87.3	96.5		500	99.1	79.7	95.0
	200	95.9	76.2	91.9		200	97.0	57.5	98.4
	100	87.8	63.0	82.9		100	92.0	44.9	93.9
50 m	75	81.6	56.0	76.5	150 m	75	87.4	39.9	89.7
	63	76.3	51.5	69.9		63	82.2	36.0	84.7
	1000	100.0	100.0	100.0		1000	100.0	100.0	100.0
	500	89.7	55.3	95.7		500	97.2	94.2	89.5
	200	79.4	34.3	89.3		200	95.6	87.6	82.5
70 m	100	67.6	26.8	80.4	170 m	100	77.7	80.8	74.8
	75	60.5	23.8	75.1		75	72.9	76.2	70.6
	63	55.3	21.5	69.2		63	67.7	71.7	67.1
	1000	100.0	100.0	100.0		1000	100.0	100.0	100.0
	500	88.5	61.1	85.4		500	93.4	87.8	96.7
90 m	200	80.0	43.9	73.2	190 m	200	83.3	71.9	93.1
	100	66.9	32.1	64.4		100	75.0	52.1	87.2
	75	60.1	29.9	60.7		75	70.5	44.7	83.0
	63	55.1	27.1	52.7		63	66.3	41.5	77.8
	1000	100.0	100.0	100.0		1000	100.0	100.0	100.0
	500	99.3	92.8	98.8		500	98.9	90.2	97.2
	200	97.3	83.1	96.8		200	97.3	82.3	93.4
	100	88.4	71.0	91.9		100	90.9	72.1	88.9
	75	84.4	64.2	88.3		75	85.6	66.7	86.5
	63	80.3	58.9	84.6		63	80.6	62.4	81.6

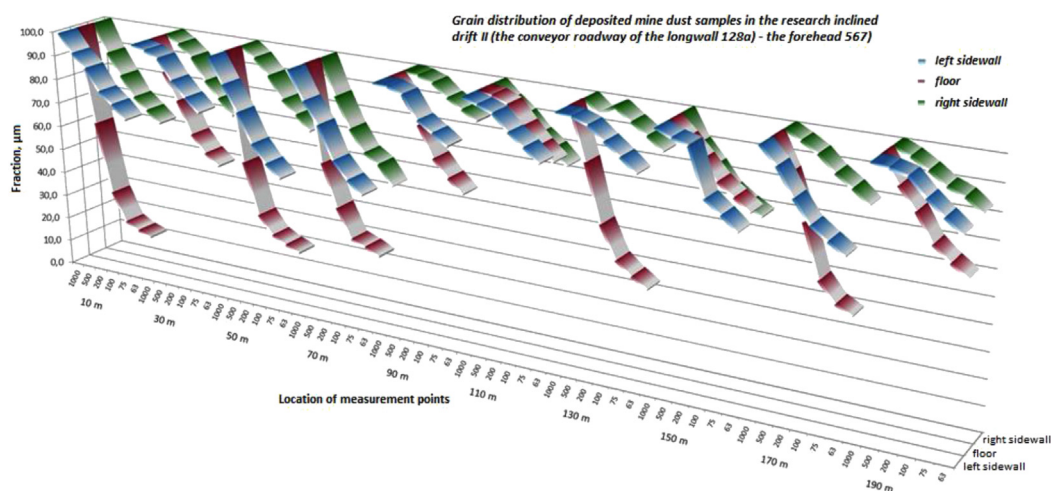


Fig. 5. Particle size distribution of deposited coal dust samples.

These fractions indicate also a lower demand of thermal energy required for the occurrence of the explosion flame.

It is assumed that coal dust with the percentage of the fraction below 0.075 mm less than 25% are classified as coarse dust, and dust with the percentage of the fraction greater than 80% are defined as very fine and highly explosive. It is essential that the study included deposited mine dust, that is a mixture of coal dust and stone dust, with a high participation of the second one, while according to the Polish Standard [16], the grain-size of anti-explosion stone dust, which resulted from sieving through the sieves with the square mesh size 0.075 mm should be at least 50%.

Under the abovementioned project, the designated fractional distributions should allow for an appropriate selection of the types of sprinkling nozzles and determination of their operational parameters (in particular, the capacity, water and compressed air pressure, direction of sprinkling) during sprinkling the safety zones [1].

Table 2 and the chart in Fig. 5 presents the size of the fractional distributions of the deposited mine dust in the research inclined drift II.

The analysis comprised the dust scope, that is the grains of dust that pass through the sieve with the mesh of 1 mm, thus the presence of this fraction in each case was 100%. The presence of the coarsest fractions of deposited mine dust were found in each measurement point, most of all on the floor of the excavation, while on the sidewalls there were settled mostly the finest fractions. The average value of the percentage presence of the fraction of dust that passes through the smallest sieves with the mesh size of 0.075 mm and 0.063 mm was respectively

67.9% and 63.2%, thus this dust was classified as fine dust. The occurrence of coarser dust fractions within the section closer to the forehead and the fraction of finer dust in further distances from the forehead was also characteristic, and it resulted from a faster, gravitational settling of heavier dust particles. It was also found that there is a dependency of occurrence of coarser dust fractions in the places where mine dust with relatively low content of non-combustible solids deposited. This dependency was particularly visible within the floor of the excavation, especially in the first dozen meters of the excavation.

4. Conclusions

The article presents an analysis of formation of the level of security of deposited dust against the threat of coal dust explosion present at the distance of the first 200 m of the safety zone maintained over the entire length of the drilled research inclined drift II (the conveyor roadway of the longwall 128a) – the forehead 567 in the colliery KWK “BRZESZCZE”. The analysis was carried out based on the results of laboratory tests of samples of mine dust deposits collected from respectively 10 measurement points evenly distributed throughout the examined area. The subject research was carried out during the implementation of the project *Modelling of the mechanism of explosive coal dust deposition in the vicinity of mined faces in terms of identification, assessment and levelling the possibility of its explosion*.

Dust explosion prevention was applied in the examined excavation, and it involved maintenance of a safety zone along the entire length of the excavation, by sprinkling with stone dust once every three days, in the amount not less than 160 kg of

stone dust per day and the maintenance of dust explosion barriers.

The dustiness with mine dust and coal dust in particular measurement points was respectively from 0.014 kg/m^3 (10 m) to 0.193 kg/m^3 (110 m) and from 0.002 kg/m^3 to 0.061 kg/m^3 , and on average 0.108 kg/m^3 and 0.019 kg/m^3 along the first 200 m of the safety zone. On average, the mine dust and coal dust deposited on sidewalls respectively amounted to 0.010 kg/m^3 to 0.002 kg/m^3 , and compared to the average amount of the deposited dusts on the floor (0.098 kg/m^3 and 0.020 kg/m^3) it was only 10.2% and 10.0%. It was caused due to the application of an MM-type net on the sidewalls (instead of concrete blocks) as lining of the support, which prevents accumulation of dust deposits on it. The differences in the amount of deposited mine dust in particular measurement points resulted mainly from the intensity of the applied dust explosion prevention.

The lowest content of incombustible solids in the deposited mine dust in individual samples was as follows: 54.3% (10 m – right sidewall), 61.8% and 63.5% (170 m and 10 m – floor) and 67.4% (10 m – left sidewall), and it was caused by an increased intensity of deposition of dust within the forehead zone. An average content of incombustible solids in particular measurement points was from 62.9% (10 m) to 96.9% (110 m), and their average content on the floor was 78.1%, on the right sidewall 81.6%, and on the left sidewall 82.1%.

Dry and fly mine dust deposited within the examined excavation area and its transient water content was from 0.1% to 3.8% (average of 0.9%).

10 sections (6 on the sidewalls and 4 on the floor) with unsecured mine dust were found on the sidewalls and floor of the research inclined drift II, however only in three cases (on the floor of the excavation), the amount of deposited coal dust exceeded the amount of 30 g/m^3 of the excavation and it was from 0.041 g/m^3 and 0.048 g/m^3 , thus it did not exceed the lower explosion limit of coal dust.

According to the requirements concerning the level of security of mine dust in the safety zones as well as location of explosion barriers within methane fields, the content of –incombustible solids in this dust should be at the level of at least 80%. Four sections (0–20 m, 51–80 m, 131–140 m, 171–180 m) were found within the area of the first 200 m of the safety zone maintained within the entire length of the examined inclined drift, where the deposited mine dust was not secured, and the content of non-combustible solids was lower than 80% and amounted from 62.9 to 71.4%. It was calculated, according to the Polish Standard (an average for 10 measurement points), that the

content of incombustible solids at the examined section of the safety zone was 75.9%, and also in this case it did not meet the requirements of mining regulations. Four measurement points were located within the dust explosion barrier. The content of incombustible solids in the mine dust deposited in these points was: 68.0%, 90.4%, 65.1% and 96.2% (average of 79.9%) and in two cases it did not meet the requirements of mining regulations. These shortcomings resulted from an ineffective dust explosion prevention and were immediately removed by dust service of the polish colliery KWK “BRZESZCZE” by application of additional sprinkling with stone dust.

The study concerning the average fractional distribution of deposited mine dust showed the presence of fine dusts in the research inclined drift II. The coarsest fractions of mine dust settled in each of the measurement points, primarily, on the floor of the mine working, while on the sidewalls those were mainly the finest fractions. On the floor of the excavation, particularly within the first dozen meters from the forehead, a greater presence of coarser fractions were found in the mine dust with lower content of non-combustible solids. The phenomenon of faster gravitational settlement of heavier dust particles closer to the forehead and finer fractions further from the forehead was also confirmed.

The research concerning the level of security of deposited dust against the threat of coal dust explosion in the drilled research inclined drift II (a conveyor roadway of the longwall 128a) – the forehead 567 in the colliery KWK “BRZESZCZE” showed that it is required to make an adjustment in terms of the applied dust explosion prevention. The adjustment should consist in differentiation of the amount of stone dust used to renew (sprinkle) the safety zone within particular sections, including in particular its initial part of 80 m and improving the accuracy in sprinkling with stone dust.

The obtained results fully confirm the hitherto observations made by the researchers in Canada and the USA on the occurrence and distribution of given fractions of dust, especially the fine ones which increase the coal dust explosion hazard, at the face of driven excavations. The conclusions formulated basing on the results indicate it is necessary to maintain safety zones where, throughout their length, stone dust, of the incombustible solid content of at least 80%, has to be applied, as it is the only measure which provides the required level of the coal-dust explosion protection. The conclusion also indicates that it is necessary to adjust the amount of the stone dust applied in the safety zones to the intensity of dust settlement. As the American

researchers suggest it may be recommended to amend Polish regulations with requirement to increase the incombustible solid content (over the 80% required nowadays) depending on the methane concentration in the air in the driven roadways.

Conflicts of interest

None declared.

Ethical statement

The authors state that the research was conducted according to ethical standards.

Funding body

This research was funded by National Center for Research and Development (Poland) under the agreement no PBS1/B2/4/2012.

Acknowledgements

The publication is based on data collected during investigations within project: *Modelling of the mechanism of explosive coal dust deposition in the vicinity of mined faces in terms of identification, assessment and levelling the possibility of its explosion*, financed by the National Centre for Research and Development under the agreement no PBS1/B2/4/2012.

References

- [1] Prostański D. Experimental study of coal dust deposition in mine workings with the use of empirical models. *J Sustain Min* 2015;14(2):108–14.
- [2] Humphreys D, O'Beirne T. Stone dust requirements and options. Report Project Number: C8011. In: The Australian Coal Industry's Research Program. Brisbane: ACARP; 2000.
- [3] Humphreys D. Stone dusting requirements and options. Report Project Number C9009. In: The Australian Coal Industry's Research Program. Brisbane: ACARP; 2002.
- [4] Humphreys D. Stone dust requirements. Report Project Number C10018. In: The Australian Coal Industry's Research Program. Brisbane: ACARP; 2003.
- [5] Harris ML, Sapko MJ, Cashdollar KL, Verakis HC. Field evaluation of the coal dust explosibility meter (CDEM). *Min Eng* 2008;60(10):74–8.
- [6] Harris ML, Cashdollar KL, Man C, Thimons ED. Mitigating coal dust explosions in modern underground coal mines. In: Panigrahi DC, editor. The 9th International Mine Ventilation Congress, New Delhi, India. New Delhi, India: Oxford & IBH Publishing Co. Pvt. Ltd; 2009. p. 143–9.
- [7] NIOSH. Coal Dust Explosibility Meter. Pittsburgh, P.A.: Department of Health and Human Services, Public Health Service, Centers for Disease Control and Prevention. NIOSH; 1997.
- [8] Cortese RA, Perlee HE. Full-scale testing of the float dust deposition meter. Report of Investigations. Pittsburgh: Public Health Service Centers for Disease Control and Prevention. NIOSH; 1998.
- [9] PN-G-04037. *Zabezpieczenia przeciwwybuchowe zakładów górniczych. Zabezpieczenie przed wybuchem pyłu węglowego. Oznaczenie zawartości części niepalnych w pyłe kopalnianym* [Polish standard - Explosion protection of collieries. Protection against coal dust explosion. Determination the content of non-combustible solids in mine dust.]. 1998.
- [10] Harris ML, Weiss ES, Man C, Harteis SP, Goodman GV, Sapko MJ. Rock dusting considerations in underground coal mines. In: Hardcastle S, McKinnon DL, editors. The 13th U.S./North American Mine Ventilation Symposium, Sudbury, Ontario, Canada. Sudbury, Ontario: MIRARCO - Mining Innovation; 2010. p. 267–71.
- [11] Amyotte PR, Mintz KJ, Pegg MJ. Effect of rock dust particle size on suppression of coal dust explosions. *Process Saf Environ Protect* 1995;73(2):89–100.
- [12] Cashdollar KL, Sapko MJ, Weiss ES, Harris ML, Man C, Harteis SP, et al. Recommendations for a new rock dusting standard to prevent coal dust explosions in intake airways. Pittsburgh: Department of Health and Human Services, Centers for Disease Control and Prevention, NIOSH; 2010.
- [13] Man CK, Teacoach KA. How does limestone rock dust prevent coal dust explosion in coal mines? *Min Eng* 2009;61(9): 69–73.
- [14] Sapko MJ, Cashdollar KL, Green GM, Verakis HC. Coal dust particle size survey of US mines. *J Loss Prev Process Ind* 2006;20(4–6):616–20.
- [15] Regulation of the Minister of Economy. Rozporządzenie Ministra Gospodarki z dnia 28 czerwca 2002 r. w sprawie bezpieczeństwa i higieny pracy, prowadzenia ruchu oraz specjalistycznego zabezpieczenia przeciwpożarowego w podziemnych zakładach górniczych [Regulation of the Minister of Economy of June, 28, 2002 on occupational safety and health, carrying out mine operations and special fire protection in underground mines. *J Laws* 2002;139. item 1169.
- [16] PN-G–11020. *Górnictwo. Pył kamienny przeciwwybuchowy* [Polish standard - Mining. Anti-explosive stone dust.]. 1994.