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Effect of ground control mesh on dust sampling and explosion mitigation

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Abstract

Researchers from the National Institute for Occupational Safety and Health's Office of Mine Safety and Health Research conducted an assessment of the effects that ground control mesh might have on rock and float coal dust distribution in a coal mine. The increased use of mesh to control roof and rib spall introduces additional elevated surfaces on which rock or coal dust can collect. It is possible to increase the potential for dust explosion propagation if any float coal dust is not adequately inerted. In addition, the mesh may interfere with the collection of representative dust samples when using the pan-and-brush sampling method developed by the U.S. Bureau of Mines and used by the Mine Safety and Health Administration for band sampling. This study estimates the additional coal or rock dust that could accumulate on mesh and develops a means to collect representative dust samples from meshed entries.

Introduction

Researchers from the National Institute for Occupational Safety and Health (NIOSH)'s Office of Mine Safety and Health Research (OMSHR) conducted an assessment of the effects that ground control mesh might have on rock and float coal dust distribution in a coal mine. The increased use of mesh to control roof and rib spall introduces additional elevated surfaces on which rock or coal dust can collect. It is possible to increase the potential for dust explosion propagation if any float coal dust is not adequately inerted. In addition, the mesh may interfere with the collection of representative dust samples when using the pan-and-brush sampling method developed by the U.S. Bureau of Mines (Owings et al., 1940) and used by the Mine Safety and Health Administration (MSHA) for band sampling.

This study estimates the additional coal or rock dust that could accumulate on mesh and develops a means to collect representative dust samples from meshed entries. Previous large-

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scale explosion testing within the Bruceton Experimental Mine (Nagy, 1981) showed that accumulations of float coal dust on the ribs and roof are sufficient to propagate an explosion even if the floor is covered with 100-percent dispersible rock dust. The recent laboratory-scale testing whose results are reported here demonstrates that if the installed mesh has been previously well rock dusted, float coal dust cannot accumulate to a sufficient depth to create a hazardous condition (less than 80 percent incombustible content). However, if meshed areas have not been well rock dusted, some mesh products may suspend sufficient coal dust, by themselves, to propagate an explosion or increase the explosion hazard.

Coal dust on mesh may not be visible from below. New dust sampling tools developed and tested at mine sites during this study were demonstrated to be capable of collecting representative mine dust samples from mesh, roof and ribs so that mine operators can verify if hazardous conditions exist.

Role of rock dust in explosion mitigation

Extensive worldwide research and post-explosion investigations have shown conclusively that coal dust explosion propagation is arrested and the development of widespread explosions prevented by properly applied and maintained, generalized rock dusting (Rice, 1911; Richmond et al., 1975; Michelis et al., 1987; Lebecki, 1991). Maximum effectiveness is achieved when rock dust is applied continuously as float coal dust is generated so that no stratified deposits of explosive dust layers accumulate on the rib, roof or floor surfaces of coal mine entries. The rate of application must also be adequate to raise the incombustible content (IC) of the mine dust to a minimum of 80 percent when dispersed (Cybulski, 1975; NIOSH, 2010).

Misinformation concerning the role of rock dust in mine explosions has led some to believe that rock dust on the mine floor and elsewhere, by its mere presence, will prevent the ignition of pure coal dust clouds. It must be understood that for rock dust to inert coal dust generated by mechanical mining, rock dust must be dispersed (or thrown into suspension) in separate particles. The individual rock dust particle must meet or exceed the specifications for rock dust of 70 percent passing through a 200-mesh sieve (30 CFR 75.2). Dispersion or entrainment of the rock dust and accumulated coal dust typically occurs during an explosion initiated by a methane ignition. Once dispersed, the rock dust can cool the flame front and quench the explosion by diluting the coal dust cloud and absorbing heat.

Other research has shown that the coal or rock dust accumulated on the rib or roof surfaces or other elevated surfaces (overhead dust) is easier to disburse or entrain into the turbulent air created by an explosion shock wave than dust on the mine floor (Nagy, 1981; Owings et al., 1940). In addition, a full-scale explosion test conducted at Lake Lynn scoured coal and rock dust on the mine floor to depths of 1 to 3 mm (0.04 to 0.12 in.) (Harris et al., 2009). Therefore, thicker layers of rock dust do not add more protection or offset accumulations of float coal dust on elevated surfaces. It is quite possible for a widespread explosion to develop in a heavily blanketed-with-rock-dust mine where the rib and roof surfaces had been neglected (Hartman and Westfield, 1956). The use of mesh increases the hazard when poor rock dusting practices are allowed.

Many researchers have demonstrated through experimental mine testing that a float coal dust entrainment of approximately 50 mg/L with no rock dust entrainment will propagate an explosion (Hartmann, 1957; Cybulski, 1975; Richmond et al., 1979; Nagy, 1981; Cashdollar et al., 1987; Weiss et al., 1989). Sapko et al. (1987) demonstrated through experimental mine testing that a 0.12-mm (0.005 in.)-thick layer of float coal dust, equivalent to a float coal dust concentration of 50 mg/L, when the float coal dust is resting on an 81.5 percent IC substratum on the floor will still propagate an explosion. They also demonstrated that float coal dust on elevated surfaces increases the explosion hazard. For example, if 10 to 30 percent of the nominal float coal dust loading of 100 mg/L is deposited near the mine roof (with the remainder on the floor substratum), the rock dust in the floor substratum must be increased to provide an 86 to 95 percent IC, respectively, to prevent propagation.

Mesh adds additional elevated surface areas on which rock or float coal dust can be suspended, which could increase or decrease protection from explosion propagation. However, if the mesh has the capacity to hold sufficient dispersible float coal dust without at least four times that amount of dispersible rock dust, an explosion may propagate.

One familiar example of elevated surfaces that accumulate dust is the conveyor belt structure. During eight mine visits by OMSHR researchers as part of this study, dust samples were collected from seven belt structures in 3.1-m (10-ft) increments and analyzed for percentage incombustible content (percent IC) using the low-temperature ashing (LTA) method (NIOSH, 2010). Table 1 shows that an average of 68 percent of the samples contained more than 80 percent IC. Of course, that means 32 percent of the samples were not in compliance, resulting in increased hazard.

Rock and coal dust tests

We conducted experiments to investigate the dust-carrying capacities of different ground control meshes and whether a new representative sampling method showed the incombustible content of the accumulated dust. We then conducted laboratory testing under controlled conditions to confirm the in-mine tests.

Rock dust accumulation on mesh

Pneumatic rock dusting was carried out in the OMSHR Safety Research Coal Mine (SRCM) to better understand how rock dust and coal dust collect on ground control mesh.

Batches of 200 pounds of rock dust were distributed in the entry using an A.L. Lee EL5-200 battery-powered rock duster. Mesh was attached to the ribs and roof at 6.2-m (20-ft) intervals over a distance of 6 to 30 m (20 to 100 ft) from the rock duster. The area is wet in the summer and typically dries out in the winter months. Testing began in December and extended through April while the mine was relatively dry and cold.

Four types of mesh were installed in the mine:10.2 cm by 10.2 cm (4 in. by 4 in.) 8-gauge welded wire, Tensar BX3326 fibrous plastic mesh, and two types of Huesker (35/35 and 80/80) woven coated fabric mesh. Laboratory testing included two additional meshes: a heavy 10.2 cm by 10.2 cm (4 in. by 4 in.) 0.64-cm (0.25-in.) wire mesh. and a DSI

Polymesh. The mesh dimensions, shown in Table 2, determined the surface area and percent of the total area that was available to support dust. Where mesh is supplied in long rolls, the machine direction is parallel to the longitudinal dimension and the cross direction is perpendicular.

The amount of dust that the compressed-air rock duster could deposit on the mesh was highly variable, depending on the mesh flexibility, nozzle exit velocity, distance from the nozzle, and moisture conditions. Three dusting methods were tried: (1) trickle dusting that distributed rock dust via the ventilation air, which accumulated the least amount on the mesh, (2) direct impingement with the handheld nozzle, which did not produce better results because the force of the rock dust and air stream directed out of the nozzle from 0.6 to 1.5 m (2 to 5 ft) from the mesh severely shook the mesh and little accumulation was observed, and (3) indirect rock dusting, which accumulated the most dust on mesh by directing the hose discharge toward the mine roof so that dust would fall from above onto the mesh, as seen in Fig. 1. Note that although the second method was not a good method for accumulating dust on roof mesh, it is an excellent method that mine operators can employ during rock-dusting efforts to remove dispersible float coal dust accumulations on mesh. At times, dust is hidden from view by a miner standing under the mesh. Aggressive rock dusting may dislodge and render inert dust accumulations. (MSHA reported that in instances where float coal dust has accumulated on mesh, timber and conveyor structures prior to the application of rock dust and has become caked, it may be difficult to dislodge the float coal dust or to add additional rock dust. Because the float coal dust may have accumulated to near the angle of repose, virtually no additional rock dust could stay on the suspended items. In this case, these areas had to be washed down with a fire hose before reapplying rock dust [Sherer, 2014].)

Collecting dust samples from meshed roof and rib areas

Several methods were tested to capture dry dust in a ventilated entry from the roof, rib and mesh. The best dust sampling results (Harris et al., 2014) were obtained with a 15-cm (6-in.)-wide, flexible, long bristle brush mounted on a 25-cm (10-in)-diameter bowl (Fig. 2). The bowl was drawn across the roof in a straight line (Fig. 3). This device did not require aggressive scraping, could be used on an extension pole to reach high areas, and was later proven to be manageable in the field. Further development of this proof-of-concept device may indicate that other dimensions and features would improve its performance.

This collection method limited the amount of dust lost compared with the traditional pan-and-brush technique. The finer-sized rock dust particles and the less-dense float coal dust particles were collected by the bowl and not swept away by the ventilating air flow. Other methods visibly lost fine particles, biasing the sample toward the coarsest or heaviest rock or coal dust particles. The relationship of particle size to collection method is important because finer particles are the most reactive in an explosion (Hartman et al., 1954; Owings et al., 1940).

The standard 15-cm (6-in.)-wide pan and 10-cm (4-in.)-wide brush (USBM band sampling tools) (Fig. 4), the roof and rib surface could not be reached, and ventilation air carried dust away. Also, dust on top of the mesh was not dislodged.

The West Virginia dust sampling methods promulgated in 2013 were not tested for this report because they were issued after this work was done. The published instructions for using the “rib brush adapter for the scoop” on an extension pole details how to sample roof dust in high entries but does not address the issue of sampling when mesh is present (West Virginia Office of Miners’ Health, Safety and Training, 2013).

We tested the bowl-and-brush method on meshed roofs at several operating mines, which demonstrated that dry dust on roof strata could be dislodged with the long bristle brush when the mesh was installed tightly against the roof strata. If the mesh was not close to the roof, the bowl could be used to raise the mesh close enough to the roof for the brush to dislodge and capture dust.

The best method for collecting meshed rib dust was a plastic half-pipe scoop and small 5-cm (2-in.)-wide brush (Fig. 5). MSHA’s pan-and-brush technique could be used on the rib mesh only when the mesh was very close to the rib, since the 10-cm (4-in.) brush was too wide to reach through the mesh to the rib itself. Care must be taken to collect sufficient sample width by making multiple passes if the rib sample will be combined with roof and floor samples to form a complete band sample.

Laboratory tests

The objective of the laboratory tests was to determine the maximum dust loading that the mesh could support, and if the dust collected using the brush-and-bowl method was representative of the total dust on top of the mesh. Rock dust and coal dust were tested separately and also layered together. Figure 6 shows a top view of one of six small test frames. Mesh was attached to the underside of the 17.1 by 19.7 cm (6.75 by 7.75 in.) central area of each frame. Each test was repeated on different days and the results were averaged to eliminate the effects of time, humidity and temperature variations on total dust weight.

The maximum amounts of rock dust and Pittsburgh Pulverized Coal (PPC) dust were determined by loading each of the six mesh types from above with a flour sifter and collecting the dust in a plastic lined tray for later weighing. The results show a strong relationship between the mesh surface area as a percentage of the total area and the weight of coal or rock dust per square centimeter of total roof area supported by the mesh (Fig. 7).

PPC was sifted on top of the maximum amount of rock dust to simulate float coal dust layered on well-rock-dusted mesh. Each mixed-dust sample was analyzed using the same LTA test performed by MSHA on all dust samples collected for compliance with the CFR 75.403 “maintenance of incombustible content of rock dust” regulation (NIOSH, 2010). This test is used to measure percent IC. The total percent ICs of the samples range from 95 to 98 percent, which shows that the ground control mesh could not suspend mine dust that had less than 80 percent IC due to float coal dust settling on the well-rock-dusted mesh. The results are listed in Table 3.

A second mixed-dust scenario was created to simulate a periodic addition of a minimum amount of rock dust to prevent buildup of combustible materials. A mine situation similar to this procedure would occur if the mesh were located near a float coal dust generation point such as a belt transfer station where the area was re-rock-dusted periodically as evaluators notice changes in color due to the accumulation of float coal dust. This is important because thin layers of PPC on top of rock dust, if left exposed to an explosion shock wave, may propagate an explosion (Hartman et al., 1956). In this mixed-dust scenario, rock dust and PPC were added multiple times in thin layers using a sifter. A minimum thickness of rock dust was placed on the mesh to visibly change it to a uniform white color. PPC was added on top of the rock dust to turn the surface color black. This process was repeated until the maximum loading condition was reached and no additional dust layers could be added. Depending on the type of mesh used, a total of four to 12 layers were required to reach the maximum loading condition. This mixture ranged from 87 to 94 percent IC, which also exceeds the minimum 80 percent IC necessary to prevent propagation.

Testing for sampling effectiveness

In order to determine if brush-and-bowl samples are representative of the in situ coal and rock dust mixtures that collect on roof mesh, total percent ICs were compared against sample percent ICs. The bowl and brush were passed under the mesh frame, and the percentage of dust captured was calculated. Totals of 23 to 91 percent of the available weight of dust on the mesh were collected, depending on the roof mesh type (see Table 3). The percent IC of the collected dust was then measured and compared against the percent IC of the dust originally loaded onto the mesh. The percent IC values are within 98 percent of the total sample values, demonstrating that this sampling method may be representative of the incombustible content of the dust on the mine roof and mesh.

Discussion

When the total roof area is covered with mesh, the worst-case situation is when only very reactive float coal dust is suspended on the mesh elevated surfaces. Hypothetically, during an explosion event, this coal dust could become entrained in the entry at the concentrations shown in Fig. 8 for four of the mesh types studied. The maximum quantity of coal dust carried by each mesh type divided by the volume of entry below the mesh is shown for four different entry heights. As the entry height increases, the greater mine entry volume reduces the entrained concentration of dust. For example, the woven coated stranded mesh with an area of 27 percent of the total roof area can carry 0.223 g/cm^2 (0.003 lb/in^2) of coal dust. In a 2-m (6.5-ft)-high entry, the coal dust that potentially could accumulate on the mesh would produce an explosive mixture of 130 mg/L of the entry volume. In comparison, the 8-gauge welded wire mesh at 8 percent of the area cannot accumulate enough float coal dust to propagate an explosion by itself. However, each of the other mesh types can suspend sufficient coal dust to exceed the minimum coal dust concentration required for explosion propagation in the absence of sufficient rock dust.

As a result of this and other research, MSHA revised its Policy and Procedures for the Prevention of Coal Dust Explosions on April 1, 2013, to better protect miners. Dust sampling procedures were presented on a training PowerPoint document (MSHA, 2013b) and documented in the Coal Mine Safety and Health General Inspection Procedures Handbook No. PH13-V-1 (MSHA, 2013a) as follows:

- Only collect upper layers of floor dust approximately 1/8th inch in depth.
- Approximately 15-cm-wide (6-inch) band sample around perimeter of entry or crosscut; Include dust on suspended items.
- Sample tool on extended handle for roofs, ribs and suspended items that are too high to reach.
- Split sample between floor and roof, ribs and suspended items if float coal dust is a factor.
- No tracking of wet areas; Sample adjacent dry areas
- For large wet areas, sample roof, ribs and suspended items.

Summary

The safety benefits of installing roof mesh to control roof and rib spalling make it attractive. At the same time, it acts as a horizontal surface that may accumulate dust. Both rock dust and float coal dust may settle on mesh or other elevated surfaces. All dispersible dust on elevated surfaces will be preferentially entrained in air before floor dust, if disturbed by a shock wave such as that produced by an explosion. Good rock-dusting practice is to mix any float coal dust with at least four times more rock dust and add rock dust to any horizontal surfaces such as mesh. In the case where float coal dust is allowed to accumulate without rock dust, a hazard will be created. Our recent laboratory-scale testing demonstrated that float coal dust accumulations, without sufficient dispersible rock dust, on some mesh products are of sufficient quantity by themselves to propagate an explosion. New dust sampling tools and techniques used during this study were demonstrated to be capable of collecting representative mine dust samples from roof mesh. The bowl-and-brush dust collection method performed quite well when the mesh was held tightly against the roof. On the rib, the MSHA pan-and-brush method could be used in most situations except where the mesh was not close to the coal rib. In these areas, the narrow scoop and brush was required to reliably collect a sample from both mesh and rib. These same tools and techniques can be used by mine operators to verify if hazardous conditions exist.

The incombustible content of a periodically or continuously rock-dusted mesh was measured at greater than 94 percent IC with coal dust on top and greater than 87 percent IC for the layered case. No samples created in these ways were found to have less than the required 80 percent IC. This applies only to dry dust that is dispersible.

Dusting technique is important when placing rock dust on mesh. Proper rock-dusting practices can mitigate float coal dust accumulations on mesh, or other elevated horizontal surfaces, and minimize the explosion hazard. It is important to dislodge any float coal dust so that it is thoroughly mixed with rock dust and add rock dust to all horizontal surfaces to prevent accumulations of float coal dust in the future. Mesh and other elevated surfaces must be carefully monitored in coal mines for adequate rock dust and limited float coal dust accumulations to avoid creating an unintended explosion hazard.

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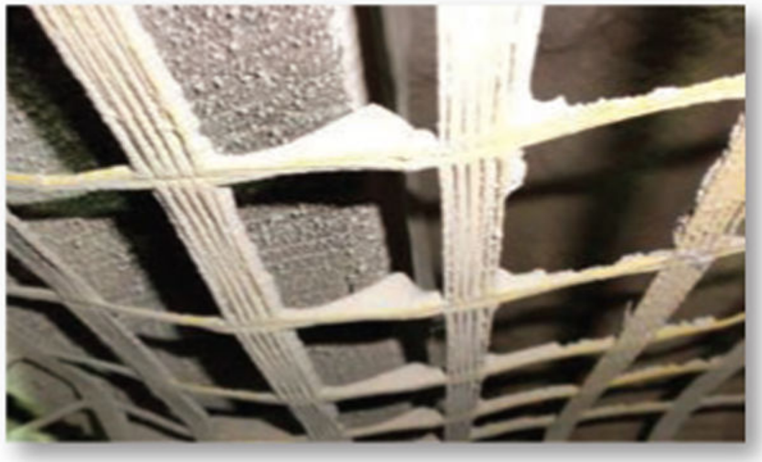

Figure 1.
Indirectly applied rock dust is visible on the elevated surface of the mesh.

Figure 2.
A long bristle brush in a bowl dust collector worked well as a collection method for dust on the roof and mesh.

Figure 3.
Using the bowl and brush to collect a roof dust sample in an underground coal mine.

Figure 4.
Dust collection from roof mesh using the MSHA pan-and-brush technique.

Figure 5.
Rib dust collection using a plastic scoop and a 5-cm (2-in.)-wide narrow brush.

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Figure 6.
Small frame with Huesker 35/35 mesh before and after loading with rock dust.

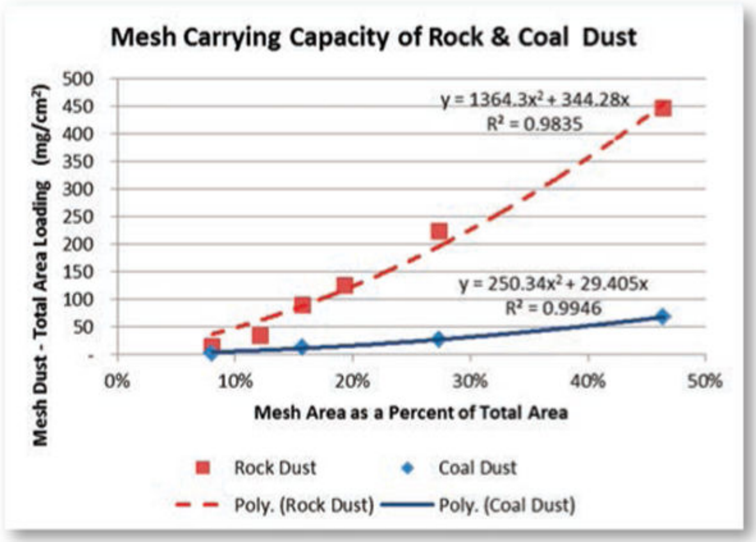

Figure 7.

Milligrams of rock and coal dust per square centimeter of total roof area supported on different sizes of roof mesh.

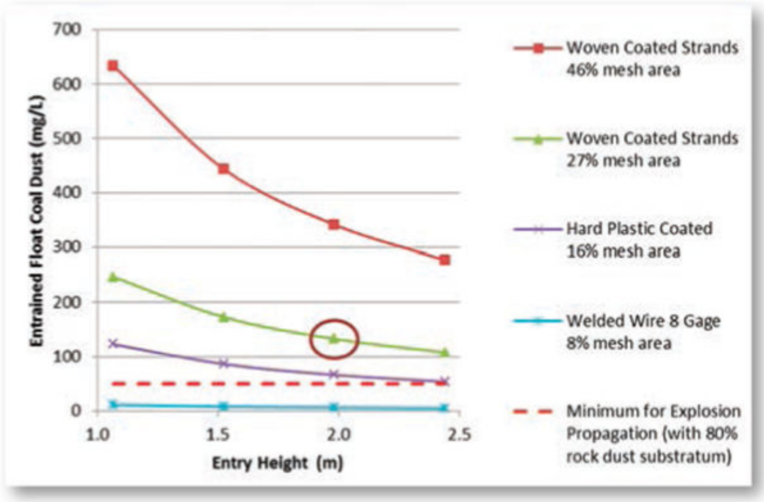

Figure 8.

Mine entry height as a function of maximum available coal dust concentrations for four mesh types.

Table 1

Percent of dust samples containing more than 80 percent incombustible dust. Samples were collected from 3.1-m (10-ft) sections of the conveyor belt structures of eight coal mines.

Mine	**A**	**B**	**C**	**D**	**E**	**F**	**G**	**H**	**Average**
Percent of samples greater than 80 percent IC	33%	20%	100%	NA	70%	50%	100%	100%	68%

Table 2

Mesh dimensions used in the mine and laboratory tests of rock and coal dust retention and capture.

Mesh type	Aperture dimensions (cm)						Comments
	Machine direction		Cross direction		Open	Mesh area	
	Centers	Opening	Centers	Opening	%	%	
Wire 4 in. by 4 in., 8-gauge	10.2	9.7	10.2	9.7	92	8	Round, rusty
Wire 4 in. by 4 in., 8-gauge	10.2	9.5	10.2	9.5	88	12	Round, rusty
Hard fibrous plastic	6.2	5.7	6.0	5.5	84	16	Flat, smooth, sharp edges
Woven coated fabric	5.8	5.3	5.5	4.8	81	19	Rubbery coating, some gaps
Woven coated fabric	6.2	5.0	5.9	5.3	73	27	Rubbery coating, some gaps
Woven coated fabric	4.1	2.5	3.6	3.0	54	46	Rubbery coating, some gaps

Table 3

Total weight of rock dust collected on four mesh types with a coating of coal dust compares well to the captured weight and IC of the sampled dust.

	Woven coated fabric	**Woven coated fabric**	**Hard fibrous plastic**	**Welded wire 10 cm open 4 cm wire**
Total sample weight (g)	122.27	63.22	27.70	3.97
Collected sample weight (g)	27.80	22.77	13.49	3.62
Percent captured	**23%**	**36%**	**49%**	**91%**
Total percent IC	96.95	97.85	95.38	95.36
Collected percent IC	95.16	95.83	94.33	94.62
Percent of original content in sample	**98%**	**98%**	**99%**	**99%**