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Full Length Article

Effects of torpedo blasting on rockburst prevention during deep coal seam mining in the Upper Silesian Coal Basin

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ABSTRACT

In the Upper Silesian Coal Basin (USCB), coal seams are exploited under progressively more difficult geological and mining conditions (greater depth, higher horizontal stress, more frequent occurrence of competent rock layers, etc.). Mining depth, dislocations and mining remnants in coal seams are the most important factors responsible for the occurrence of rockburst hazards. Longwall mining next to the mining edges of neighbouring coal seams is particularly disadvantageous. The levels of rockburst hazards are minimised via the use of rockburst prevention methods. One active prevention method is torpedo blasting in roof rocks. Torpedo blastings are performed in order to decrease local stress concentrations in rock masses and to fracture the roof rocks to prevent or minimise the impact of high-energy tremors on excavations. The estimation of the effectiveness of torpedo blasting is particularly important when mining is under difficult geological and mining conditions. Torpedo blasting is the main form of active rockburst prevention in the assigned colliery in the Polish part of the USCB. The effectiveness of blasting can be estimated using the seismic effect method, in which the seismic monitoring data and the mass of explosives are taken into consideration. The seismic effect method was developed in the Czech Republic and is always being used in collieries in the Czech part of the coal basin. Now, this method has been widely adopted for our selected colliery in the Polish part of the coal basin. The effectiveness of torpedo blastings in the faces and galleries of the assigned longwall in coal seam 506 has been estimated. The results show that the effectiveness of torpedo blastings for this longwall was significant in light of the seismic effect method, which corresponds to the in situ observations. The seismic effect method is regularly applied to estimating the blasting effectiveness in the selected colliery.

1. Introduction

One of the natural hazards occurring in collieries in the Upper Silesian Coal Basin (USCB) is rockburst. This kind of disaster has been continuously investigated for many years (e.g. Budryk, 1938; Pelnar, 1938; Parysiewicz, 1966; Straube et al., 1972; Konopko, 1984; Holecko et al., 1999; Dubiński and Konopko, 2000; Takla et al., 2005; Drzewiecki and Kabiesz, 2008; Holub et al., 2011).

The occurrence of rockburst during underground mining process leads to the development of rockburst prevention methods. These methods are generally divided into two types: passive and active. Within active rockburst prevention methods, torpedo blasting (long-hole destress blasting) in roof rocks plays an important role. The main purpose of torpedo blasting in roof rocks is to reduce stress concentrations occurring in these rocks, although the generation of rock fractures is also important due to the creation of zones in which the energy of strong tremors can be dissipated. This type of destress blasting has been widely used in the USCB for many years (e.g. Dvorsky et al., 2003; Dvorsky and Konicek, 2005; Przeczek et al., 2005; Konicek and Przeczek, 2008; Konicek et al., 2011).

The estimation of the effectiveness of torpedo blasting is a critically important issue, especially in mining close to the mining edges of previously mined coal seams. The probability of seismic activity and rockburst is high in such mining. Torpedo blasting is the main form of active rockburst prevention method used during the longwall mining of coal seam 506 in our selected colliery in the

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Polish part of the USCB. Disadvantageous geological and mining conditions, especially the large depth of exploitation, the mining edges of neighbouring coal seams 418 and 502 and the fracturing of thick sandstone layers deposited above coal seam 506, are the main factors responsible for the high level of seismic and rockburst hazards.

To mitigate the above-mentioned hazards, active rockburst prevention method, mainly in the form of torpedo blasting, was applied in the faces and galleries of the assigned longwall in coal seam 506. The effectiveness of the torpedo blastings for rockburst prevention has been estimated via the seismic effect method (Konicek et al., 2013).

2. Geological and mining conditions

Coal seam 506 is deposited at a depth between 1018 m and 1057 m below the surface. Longwall mining of coal seam 506 was performed at the extracting level. The thickness of the coal seam near the longwall cross-cut was about 2.5 m, due to the joint with coal seam 505/1. The thickness of coal seam was finally measured to be 1.4–1.65 m. Coal seam 506 is separated from coal seam 505/1 (with thickness of 0.65–0.95 m) by a layer of shale with thickness of 0.8 m. The dip angle of coal seam 506 equals 5°–12°, generally to the south. The lithological structure of the rock mass in the area is shown in Fig. 1. The direct roof of coal seam 506 consists of shale and sandy shale rocks. Locally in the direct roof, a layer of sandstone exists. In the roof, three thick layers of sandstones are present, 39 m, 60 m and 104 m above coal seam 506, respectively (see Fig. 1). Fracturing of these thick layers of sandstone was mainly responsible for the occurrence of high-energy tremors. The floor of coal seam 506 encompasses thin layers of shale and sandy shale; below them, a sandstone layer is deposited (Fig. 1).

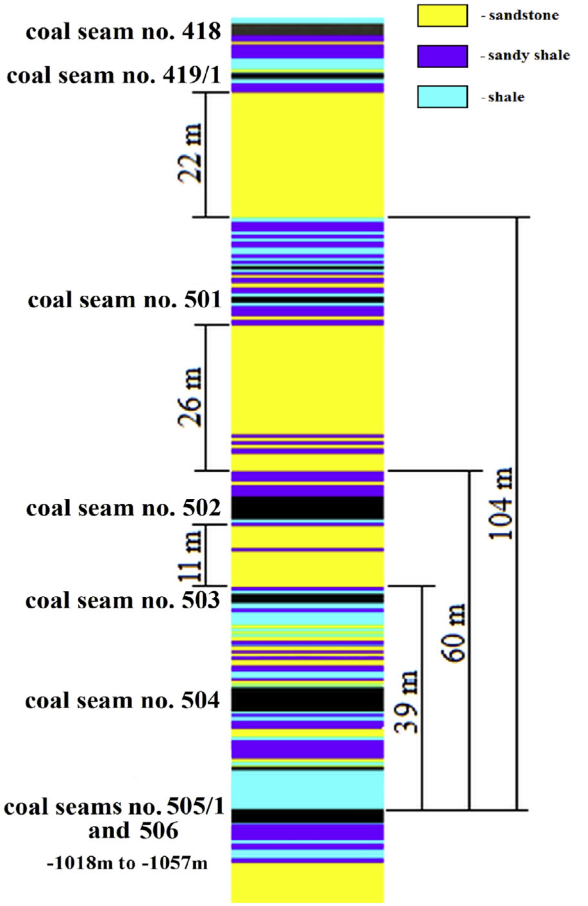

Fig. 1. Lithological structure of rock mass in the area of longwall in coal seam 506.

The selected longwall had been designed with caving, mainly between galleries 2 and 3, which is shown in Fig. 2. The longwall initially advanced from the east, near fault I (throw $h = 50$ m), and then advanced to the west along the diagonal fault (throw $h = 110$ m). The end of the longwall was arranged to the east of the protecting pillars for drifts on the levels of 840 m and 1000 m. Mining edges of coal seams 418 and 502 (130–141 m and 60–82 m above seam 506, respectively) were present above the longwall field. The longwall mining of coal seam 506 lasted for nearly two years. Longwall face advances are shown in Fig. 2.

Other disadvantageous factors affecting the hazard level of rockburst are the depth of exploitation (up to 1057 m) and the corresponding high in situ stress level (24.5–31 MPa), the tendency of coal seam 506 to burst (uniaxial compressive strength $R_c = 28$ MPa), and the occurrence of local faults with maximum throw of 2.2 m.

Further exploitation of other coal seams in this part of the coal bed will continue, according to exploitation range of coal seam 506. From this point, clear longwall mining has strategic importance.

3. Seismic monitoring method

The seismic network consisted of 16 seismic stations, located in underground excavations with depths ranging from 320 m to 1000 m. Vertical-component sensors including SPI-70 seismometers and DLM-2001 geophones composed the network; however, seismometers were the main component. The sampling rate was 5000 samples per second, with the time provided by global positioning system (GPS). The average error of epicentral location ranged from 35 m to 53 m, while the average error of hypocentral location ranged from 63 m to 71 m. Generally, the error of source location increases from the west to the east, because the seismic stations are located mostly in the west. The configuration of the seismic network used for the seismic monitoring of studied longwall is presented in Fig. 3, in which the squares marked with "S" represent the seismic stations. By using the seismic network, a dataset to study the site was obtained.

The seismic energy E_{ICM} of tremors was calculated using numerical integration method. The square of the amplitude in the following samples, sampling rate, distance between focus and seismic station, density and attenuation coefficient of rock mass, seismic wave velocity, and the calibration factors, were the parameters for energy calculation on each seismic station. Each tremor had a specific seismic energy E_{ICM} by averaging the calculated values of all seismic stations.

The intensity of seismic activities recorded during longwall advance indicated that high-level rockburst hazards were observed in this excavation. The aforementioned difficult geological and mining conditions were reflected in the observed seismic activities. The total number of recorded seismic events during the study period was 2190, with a total released tremor energy of 3.8×10^8 J. A total of 95 high-energy tremors occurred: 73 events with energy in the order of 10^5 J ($1.68 \le M_L < 2.21$; M_L is the value of local magnitude), 20 events with energy in the order of 10^6 J ($2.21 \le M_L < 2.74$), one tremor with energy of 3×10^7 J ($M_L = 2.99$) and one tremor with energy of 2×10^8 J ($M_L = 3.42$). The values of M_L have been calculated according to the formula given by Dubiński and Wierzchowska (1973). The strongest tremors (3×10^7 J and 2×10^8 J) were associated with the activation of the diagonal fault. The occurrence of the other high-energy tremors was a consequence of fracturing of the thick layers of sandstone deposited in the roof of coal seam 506. Also, the influence of mining edges of