International Journal of Rock Mechanics & Mining Sciences 83 (2016) 162–169

Contents lists available at ScienceDirect

International Journal of
Rock Mechanics & Mining Sciences

journal homepage: www.elsevier.com/locate/ijrmms

Technical Note

An attempt to determine the seismic moment tensor of tremors induced by destress blasting in a coal seam

Łukasz Wojtecki [a], Maciej J. Mendecki [b,*], Wacław M. Zuberek [b], Małgorzata Knopik [b]

[a] Kompania Węglowa S.A., Katowice, Poland
[b] University of Silesia, Faculty of Earth Sciences, Department of Applied Geology Sosnowiec, Sosnowiec, Poland

ARTICLE INFO

Article history:
Received 18 June 2015
Received in revised form
3 November 2015
Accepted 1 January 2016
Available online 15 January 2016

Keywords:
Destress blasting
Rockburst hazard prevention
Seismic moment tensor inversion

1. Introduction

Underground mining of coal seams is accompanied by rockburst hazard, which determines the application of active rockburst prevention, where destress blasting takes an important place.[1] The purpose of destress blasting is to fracture the structure of coal seam in vicinity of excavation and reduce stresses occurring in the coal seam. Tremors provoked by destress blastings typically have low energy, especially in comparison with tremors provoked by torpedo blastings. After these blastings the tremors are very often not recorded, which-in the case of a properly designed seismological network-proves that there are no stresses in rock mass and no destressing caused by blasting. In some cases, destress blastings provoked tremors with higher energy, sometimes much higher than it would appear from the weight of used explosives, which testifies to greater reduction of stress level and effectiveness of destress blastings. At present, the energy from provoked tremors is the main parameter for estimation of destress blasting effectiveness in hard coal mines. This energy is related to the value of stress reduction in rock mass.[2] Destress blasting in hard coal seams has been adopted to manage cutter roof failure, floor heave, rock bursts and coal bump.[3] When rock burst hazard is high, the destress blasting is used as an active prevention approach reducing the rock burst hazard near endangered openings. After blasting in the case of rock burst hazard, provoked tremors (sometimes rock bursts) are occurring intensity after blasting and therefore the waiting time after blasting (usually 30–40 min in Polish conditions) has been introduced to protect the mining crew against possible accidents connected with stress release events. The parameters of blast-hole geometry and blasted explosive charge depend on local mining and geological conditions and are changing respectively. Therefore, the estimation of blasting effectiveness is an important and significant task. The destress blasting effectiveness and state of rock stress evaluations acquire significance during exploitation under difficult geological and mining conditions producing high probability of rockburst hazard. Therefore, knowledge about processes which take place in rock mass as a result of destress blasting becomes an important issue.[1,3]

To determine the processes in tremor foci, the method of seismic moment tensor inversion can be applied. Focal mechanism describes characteristic movement of rock masses in tremor source, determined by a system of pair of forces. During this movement from the focus, a specific system of seismic waves is emitted. Focal mechanism may be calculated by seismic moment tensor inversion method based on the analysis of seismic waves emitted from the focus and registered by an appropriate number of seismic stations, located optimally and surrounding the focus.[2,3] The seismic moment tensor inversion method was first used in global seismology[4] and was subsequently adapted to mine tremor analysis.[2,5–12]

Seismic moment tensor inversion method has been used to determine the focal mechanisms of tremors provoked by destress blastings performed in the operating longwall face in the 510 coal seam belonging to one of the Polish hard coal mines in the USCB. Next, processes that occurred in the foci of provoked tremors were

---

[*] Correspondence to: University of Silesia, Faculty of Earth Sciences, Department of Applied Geology Sosnowiec 60 Bedzinska Str., Sosnowiec 41-200, Poland

E-mail address: maciej.mendecki@us.edu.pl (M.J. Mendecki).

http://dx.doi.org/10.1016/j.ijrmms.2016.01.002
1365-1609/

determined and the estimation of active rockburst prevention effectiveness was evaluated.

2. Geological and mining conditions in the area of the investigated longwall

The 510 coal seam in the area of investigated longwall is deposited at the depth of about 840 up to 910 m below the surface and its thickness varies from 5.3 m to 8.1 m. The smallest thickness of the coal seam is observed near to the local fault zone.

Sequence of shale, sandy shale and fine-grained sandstone is deposited in the floor of the 510 coal seam. In turn, complex of sandy shale, fine-grained sandstone, sandy shale and shale occur in the coal seam roof (Fig. 1).

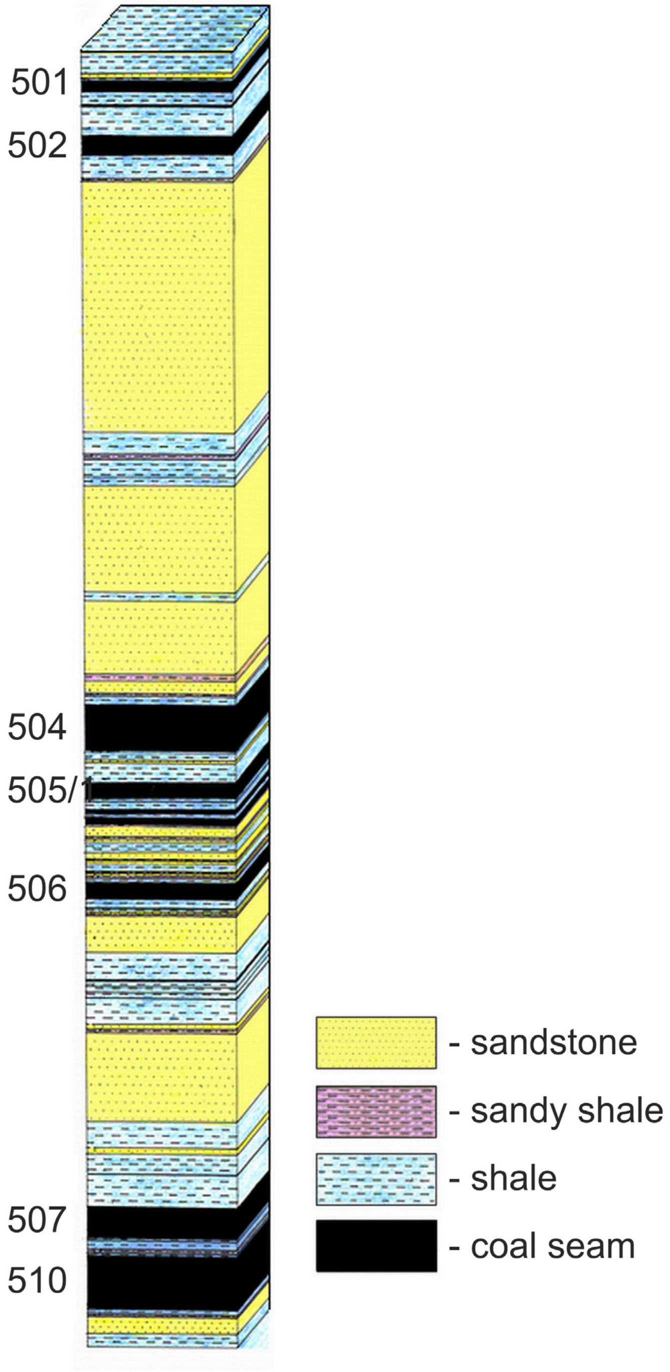

Fig. 1. Lithological structure of rock mass in the area of the investigated longwall.

Total thickness of the roof layers does not exceed 13 m. The floor of the 507 coal seam is situated above. At the depth of more than 70 m above the 510 coal seam, a thick layer of sandstone is also deposited and is characterized by high value of uniaxial compressive strength (up to 80 MPa), and its thickness – with some thin interlayers of shale and sandy shale – reaches maximally 60 m.

In the vicinity of the investigated longwall, there is a local fault zone (Fig. 2). This zone consists of several faults, with strikes from SW-NE to WNW-ESE, throws from 0.2 m to 5.5 m, and dips from about 20° to 90° (generally SE, but S and NW as well).

The studied longwall, exploited with caving, was running in the upper layer of the 510 coal seam, from the West to the East. The longwall started from the vicinity of protection pillar for flank drifts and in the short distance from fault characterized by NW-SE strike and throw of 25 m. And it was running along a gob exploited in the upper stage.

The entire investigated longwall was also running under a gob exploited in the 507 coal seam. In addition, the 502 coal seam, deposited at the distance of about 126 m above the 510 coal seam, had also been mined earlier. What is more, the studied longwall passed under the remnant of irregular shape in the 501 coal seam, deposited at the distance of about 140 m above the 510 coal seam. This remnant was probably responsible for the observed increase in stress in rock mass during the investigated longwall run. Fig. 2 also depicts monthly longwall advance (from November, 2012 up to December 2013).

Total number of recorded high energy tremors was 61 including: 46 events with energy E of 10^5 J ($1.68 \leq M_L < 2.21$), 14 events with energy E of 10^6 J ($2.21 \leq M_L < 2.74$) and one tremor of energy $E = 1 \cdot 10^7$ J ($M_L = 2.74$). The tremor energy calculation based on the numerical integration of seismograms where the seismic source-seismometer distance, the attenuation coefficient and the gain of channel were taken in consideration. At the same time, the local magnitude was determined from seismic energy using the formula presented below[13]:

$$\log E = 1.8 + 1.9M_L \tag{1}$$

The high-energy tremors had the most influence at the level of rockburst hazard in the investigated longwall. The sudden dynamic impact on coal seam, caused by tremors, could lead to a coal bump. It was assumed that if the stress level in coal seam is high, the probability of rockburst occurrence increases.

3. Active rockburst prevention in the investigated longwall

To minimize the rockburst hazard in the area of the investigated longwall, active rockburst prevention was applied. Periodic blastings, destressing the 510 coal seam, were performed from the longwall face. The purpose of these blastings was to change structural properties of coal and to reduce the coal seam ability to rockburst under the disadvantageous and associated occurrence of local fault zone, gob exploited in the upper stage and the remnant in coal seam no. 501 (Fig. 2).

Blast-holes were drilled in the operating longwall face perpendicular to the longwall face. The blast-holes were 12 m long with the diameter of about 42 mm. In each blast-hole 5 kg of explosives were charged, which occupied nearly 5 m of total length of the holes. The rest of each blast-hole was filled with clay stemming. The number of the blast-holes was variable and depended on the location of the local faults (it ranged from 6 to 12 blast-holes). The interval between blast-holes was about 10 m. Before every blasting the crew was removed from the longwall.