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Geomechanical conditions of causes of high-energy rock mass tremors determined based on the analysis of parameters of focal mechanisms

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ABSTRACT

The aim of the research was to determine the cause of high-energy rock mass tremors (energy $E \geq 10^5$ J) in the area of longwall H-2a located in seam 409/3 in Borynia-Zofiówka-Jastrzębie colliery, basing on the analysis of geological and mining conditions, seismic activity, focal mechanism and local stress field. The research employed the method of seismic moment tensor inversion which provides parameters of focal mechanism (percentage share of its components: isotropic, uniaxial compression or tension, shear component; trend and dip of nodal planes, directions of tension axes and compression stress). The parameters describe processes occurring in focuses of tremors and they are clearly linked with stress conditions in a given area. The conducted tests showed that the cause of occurrence of high-energy tremors and three rockbursts in lot H while mining seam 409/3 with longwall H-2a, was dynamic destruction of roof rocks which could displace towards the cavity created after mining the seam. An additional factor significantly magnifying the process was the share of stresses, which originate from the faults in the area, existing in the rock mass. Results of the research provided additional information to determine the degree of rockburst hazard in the area. Because of very dangerous work conditions (stress parameters reflect the rock mass of high shear strength, where dynamic influence of tremors is stronger) mining activity in longwall H-2a was terminated a few dozen metres earlier than it had been originally planned.

1. Introduction

Underground mining of coal deposits disturbs equilibrium of a system of natural stresses in the rock mass, both in direct vicinity and further away from mine workings. The process results in, among others, rock mass tremors, which in some cases are a direct cause of rockbursts. The phenomenon of rockburst, due to its dynamic character, causes certain effects in workings within its range. These may be accidents of the personnel and material loss in form of destroyed or damaged machines, equipment and workings losing their functionality. Unfortunately, these are often incidents of a mining catastrophe scale i.e. a group accident with casualties and seriously

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wounded personnel. That is why research works on developing more efficient preventive measures, which would reduce the threat, are conducted in many research centres in Poland and around the world. Seismic phenomena and rockburst hazard associated with it in a given longwall panel are influenced by a number of natural and technical factors. The dominant ones are strength parameters of coal and surrounding rocks, and the volume of stresses in the vicinity of operating workings (Bukowska, 2013; Dubiński, 2013). As it is known the source of high-energy mining tremors are fracturing layers of high strength rock mass (Drzewiecki & Kabiesz, 2008). The process of fracturing rocks in a focus can be determined basing on parameters describing the focal mechanism of tremors. The parameters are calculated with seismic moment tensor inversion basing on the analysis of seismic waves generated in a tremor focus and recorded by sufficient number of seismometers located around the focus. Parameters of a focal mechanism are fundamental for determining a relative local stress field described with the direction of principal stresses and their mutual relations, which in turn enable evaluating stress state of the rock mass of higher or lower tendency to generate high-energy tremors. It ought to be noted that the spatial system of principal stresses axes determines occurrence of tremors of various focal mechanism (Stec, 2012). Of course, basing only on seismologic data, it is impossible to determine absolute values of stress. Yet, it is possible to determine their spatial orientation and mutual relations. It turns out that tremors of different focal mechanisms, i.e. with different spatial seismic influence, can have a different influence on the process of destroying the structure of rock mass and losing stability in the already existing, or just forming, planes of weakening. Hence an analysis of focal mechanism tremors, especially high-energy seismic phenomena, started to play an important role in determining causes and occurrence of tremors, and for rockbursts, which caused damage to the mine workings, it became a standard procedure (Stec & Drzewiecki, 2012). Calculations of focal mechanism parameters, and according to them local stress field were conducted for high-energy rock mass tremors which accompanied mining seam 409/3 with longwall H-2a in Zofiówka colliery.

2. Characteristics of the tested area

The tested area covered longwall H-2a, seam 409/3, lot H, of Zofiówka colliery. Seam 409/3 occurring within a group of seams 409 in the monoclonal part of the seam, of approximately 10° eastward dip, has a complicated structure. Eastward and southward its thickness increases from approximately 1.6 to 2.6 m, and in the southern part of the discussed area a 0.80 m layer of coal gets separated from its top (distance 0.3–1.0 m). Seam 409/3 in the area of longwall H-2a occurs at the depth of between 840 m and 950 m. In the eastern part of lot H there is the "eastern" fault of N–S strike and eastward drop h = 25–15 m; the western border of the lot is Jastrzębie fault, also of N-S strike and westward drop h = 25–50 m (Fig. 1). The disturbances are accompanied by parallel faults of drop of up to 3 m. Normal fault of drop of approximately 5 m runs, roughly W-E, through the central part of lot H. Geological structure of the rock mass, both above and below seam 409/3, shows diversified lithology. In the roof of the seam there are: sandy mudstone, locally with single laminas of coal (0.0–0.90 m), siltstones (0.0–2.25 m). Then there is sandstone, with intercalations of siltstone (12.0–41.0 m) of R_C = 61–106 MPa, locally in the immediate roof strata of the seam. Above there is siltstone, with intercalations of fine-grained sandstone (~0.0–15.0 m), mudstone with laminas of coal (0.0–2.70 m), and seam 409/2 (~0.78–0.85 m). Over seam 409/2 there is siltstone, with local laminas of mudstone (0.0–4.0 m), and then a layer of thick-bedded sandstone of thickness between 15.0 m and 22.1 m. Floor layers of seam 409/3 also show geological diversification. In the floor of the seam there are: mudstone with thick laminas and layers of coal, locally of coal shale characteristics (0.50–1.30 m), and seam 409/4 of thickness of 4.2–5.2 m. In the area of longwall H-2a there are four edges of previous mining activities i.e. seam 408/2 at the distance of 64–73 m, seam 406/1 at the distance of 173–198 m, seam 404/4 at the distance of 223–251 m, and seam 409/4 at the distance of 0.4–20 m (Fig. 1). Seam 409/3 in lot H is ranked as: III degree rockburst hazard, I degree water hazard, IV category methane hazard, class B coal dust explosion hazard, and methane-and-rock outburst hazard.

Exploitation of longwall H-2a, with roof cave-in from east westward up the rise of seam, started on 10 June 2013. Because of potentially high seismic hazard in the area (III degree of rockburst hazard) torpedo blasting of the roof of seam 409/3 from the gateroads was conducted within the framework of active rockburst prevention. Zones of particularly high rockburst hazard were determined in tailgate H-2, where slim holes were drilled two times a week. There were also three series of seismic measurement (geotomography). The basic goal of geophysical interpretation of underground seismic measurement results is to determine the distribution of seismic wave propagation velocity in the medium being (coal seam or adjacent strata) that could reveal its structural features or their changes. The criteria characterising the anomalies of seismic P-wave propagation velocity have been implemented by Dubiński and Dworak (1989). The obtained values of a seismic anomaly showed influence of the edge of seams 408/2 and 406/1, and average increase in stress in the longwall lot.

Since the very beginning of the mining activity in the area there has been seismic activity which caused high rockburst hazard. While operating longwall H-2a and driving a recovery room for the powered roof support sections 99 tremors of energy of 10^2 J, 360 tremors of energy of 10^3 J, 84 tremors of energy of 10^4 J, 13 tremors of energy of 10^5 J and 4 tremors of energy of 10^6 J were recorded. There were three tremors among them which resulted in certain effects in the workings. On 6 November 2013 there was a rock mass tremor of energy of $E = 4.6 \cdot 10^6$ J, located in longwall gobs. The tremor caused destressing the rock mass in tailgate H-2 of seam 409/3, and exceeding the acceptable concentration of methane in the sensors installed in the area. There was damage to the gateroads (floor heave) and the gateroad support. After the tremor, mining activities were paused until 20 December 2013 when they were resumed. Yet, on 30 January 2014 there was another rock mass tremor of energy of $E = 3.7 \cdot 10^6$ J, located along the face of longwall H-2a, which caused separation of sidewalls and damaged several