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Stress changes and seismicity monitoring of hard coal longwall mining in high rockburst risk areas

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ABSTRACT

Rockburst represents a very dangerous phenomenon in deep underground mining as well as in underground constructions in unfavourable conditions (great depth, high horizontal stress, proximity of important tectonic structures, etc.). The rockburst problem relates to the natural and mining conditions of the rock mass. It is very difficult to decide which of the factors prevails, but we generally assume that it is the occurrence of competent rock layers in the rock mass. The destress blasting method is a very important rockburst control technique aims to competent rocks.

The case study describes the control of rockburst risk by destress blasting in an example of a longwall of the Upper Silesian Coal Basin. Monitoring of stress changes and induced seismicity was implemented in the selected longwall here and a description of these techniques is given. The paper describes the natural, geomechanical, and mining conditions of the investigated locality in detail. Stress changes ahead of the advancing longwall face as well as registered induced seismicity depending on the longwall advance are analysed, including the application of the destress blasting technique. Stress release efficiency, as one goal of the destress blasting technique, is analysed according to the registered seismicity using the authors' own methodology: seismic effect calculation.

1. Introduction

Stress changes and seismicity monitoring are a very important part of rockburst prevention during hard coal underground mining (e.g. Brauner, 1994; Mendecki, 1997; Holecko et al., 1999; Takla et al., 2005; Drzewiecki and Kabiesz, 2008; Feng et al., 2017; Ptacek et al., 2017) as well as in underground construction under conditions of great depth and high horizontal stress (e.g., Wang et al., 2012; Mazaira and Konicek, 2015; Zhang et al., 2016; Feng et al., 2015a,b, 2017; Feng, 2017). The presented outputs of the research project comprise stress monitoring, primarily of the changes induced by longwall mining or destress blasting, which were carried out in a mine of the Ostrava-Karvina Coalfields (OKC) within the Czech part of the Upper Silesian Coal Basin (USCB; see Fig. 1). The fracturing of rock mass due to mining is associated with the release of a considerable volume of elastic energy in the environment with the occurrence of competent strata in the coal-seam overburden, stress changes in the rock mass, and the occurrence of induced seismicity. Fracturing of the rock mass is accompanied by the formation of seismic events, which can be manifested in some cases under unfavourable conditions, as rockburst with damage to underground openings. Destress blasting is one of effective measures that impacts on the stress field as well as helping to fracture rigid competent overlying rock mass at a time when workers are not present (e.g. Krzyzowski, 2002; Konicek et al., 2011, 2013; Wang et al., 2014; Dvorsky and Konicek, 2005; Wojtecki and Konicek, 2016). For optimal use of this method as well as for the proper design of longwall mining, it is necessary to know the stress changes induced by longwall mining with application of the destress blasting technique. Verification of the stress field response to stresses induced by different geological or mining factors was the main aim of the research project. The monitored longwall extracted seam has a thickness of approximately 5 m, is at a depth about 740 m, and lies within the Czech part of the USCB. Monitoring of stress changes in the region of the advancing longwall was carried out using six stress probes (e.g. Stas et al., 2004, 2008, 2011). In all, six boreholes were instrumented with Compact Conical ended Borehole Monitoring (CCBM) probes for continuous stress monitoring of the stress–strain changes due to mining and the destress blasting effect. Data of the stress changes in all six probes were recorded first weekly and then, after advance of the longwall, daily. Analysis of the stress changes was based on the idea of original stress distribution, which is based on long-term experiences of rock mass behaviour in similar geological and mining conditions. For all probes, the magnitudes of stress changes as well as the induced seismic activity in the explored longwall were investigated. An analysis of the measured stress changes

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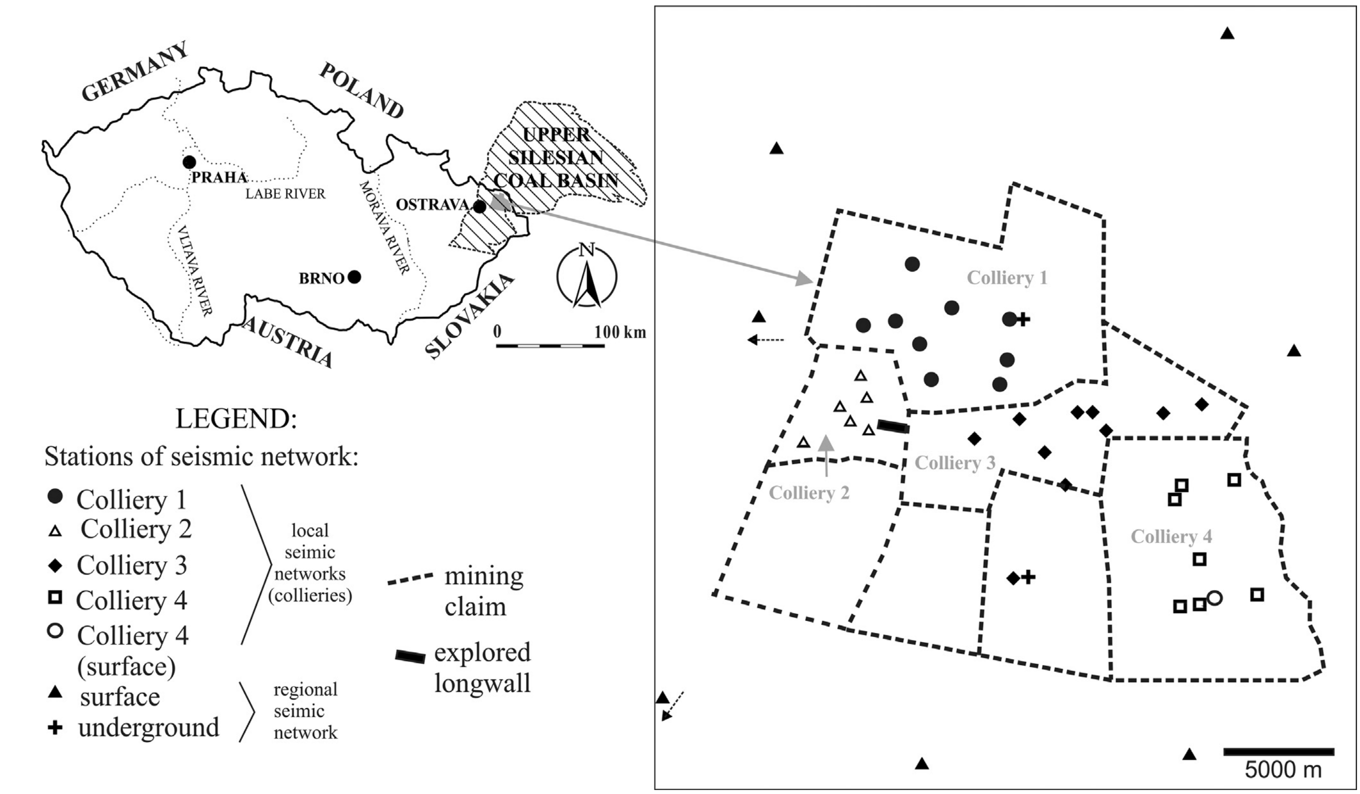

Fig. 1. USCB location and map of seismic networks.

ahead of the advancing longwall face and the registered seismicity is presented in the paper in the light of geological, geomechanical, and mining conditions of the investigated area and long-term experiences in this field. The impact of large-scale destress blasting as a proactive rockburst measure on the stress field is evaluated in the paper as well. A comparison of the monitored stress changes with the 2D modelled stress changes is presented in the paper in suitable cross-section parallel to the longwall advance. This knowledge is essential for the purpose of prevention of rockburst because the actual stress state is fundamental to its proper and operative planning.

2. Geomechanical conditions

2.1. Natural conditions

In order to verify the rock-mass stress state and its changes induced by longwall mining and destress blasting, the monitoring of changes in rock-mass stress in connection with the mining out of longwall face no. 140 704 of coal seam no. 40 was suggested. The concerned longwall is situated in the seventh mining block of the Lazy Mine. The mining area is located in the Czech part of the USCB, specifically in the western part of Karvina subbasin (see the grey area in Fig. 1). Tectonically, the USCB is one of the most complicated Palaeozoic molasses basins of the European Variscides (Ptacek et al., 2017). The tectonic structure of the basin is polytypic and conspicuously zonal. Its tectonic structure is the result of complex overthrust-fold deformations, as well as relatively simpler fault structures of subsidence and transtensional tectonics (see Dopita et al., 1997). From a sedimentary point of view, the USCB is a typical multiseam deposit with a lot of mineable seams. The concerned part of the rock mass is the part of Sedlove Member where competent rock layers between coal seams predominate. The complex tectonic structure, the character of the rock mass, and al lot of mining at seam level by the longwall method of controlled caving are reflected in complicated stress-deformation conditions of the rock mass.

The seam concerned, no. 40, is found at an average depth of 740 m below the surface (Jiránková and Waclawik, 2013). The incline of the strata in the seventh mining block is variable. The anticline axis divides this area into two parts (e.g. Grygar and Waclawik, 2011; see Fig. 3). The seams have an incline of 8° to the WNW in the western part and 7° to the NNE in the eastern part. The area of the seventh mining block is demarcated by the colliery border in the east, tectonic fault C with amplitude of 15 m in the south, and tectonic fault A with an amplitude of 5 m in the north (see Fig. 3).

The carboniferous rock mass consists mostly of solid siltstones, sandstones, and conglomerates with uniaxial compression strength between 70 and 90 MPa. The uniaxial compression strength of coal is usually between 20 and 25 MPa, rarely reaching 35 MPa (Ptacek et al., 2015). The interbedded strata between seam 39 and the overlying seam 38 has a thickness of 27 m. Seam 39 has a thickness of 4–6 m in the area. The interbedded strata between seams 38 and 39 are built mostly of fine-grained and medium-grained sandstones. The interbedded strata between seams 40 and 39 have an average thickness of 55 m and are built mostly of fine-grained and medium-grained sandstones. Medium-grained conglomerates create irregular intercalations (see Fig. 2). The physical mechanical properties of competent strata layers are connected with brittle deformation due to progressive mining operations (Jiránková, 2010, 2012). The thickness of the seam is very variable here too; on average it reaches about 4.5 m. In the eastern part, erosive sandstones lie on the seam, whose thickness is about 3 m. In the seventh block, seam 40 is developed in a direct roof of irregular siltstone, with a variable thickness of 1–13 m, which is locally eroded by superposed sandstones (see Fig. 2).

2.2. Mining conditions

The geomechanical conditions are unfavourable and the rockburst risk is extremely high in the seventh mining block. According to previous knowledge and the record of many heavy rockburst occurrences with fatal consequences (seven rockburst occurrences in coal seam no. 38 and one in coal seam no. 39), the mining block has been listed as one