THE SYSTEM OF PREDICTING AND PRECAUTIONS AGAINST INRUSHES OF MOIST ROCK INTO COAL MINE

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ABSTRACT

Sudden inrushes of water and moist rock together with other dynamic phenomena in rock masses are ranked among the most dangerous occurrences in underground mining. Also coal excavation in the Trbovlje-Hrastnik Coal Mine is frequently accompanying by sudden inrushes of water and mud. This contribution presents the results of investigations whose objective was to determine the criteria for safe mining works in the Trbovlje-Hrastnik Coal Mine. The subject discussed includes the categorization of coal blocks respect to the hazard level of sudden inrushes, technological process of coal winning from the aspect of inrush prevention, as well as the detection of hazardous moist rock "traps" and the prediction of inrush hazards.

INTRODUCTION

Coal excavation in the Trbovlje-Hrastnik Coal Mine is frequently accompanied by inrushes of water and mud. The consequences of these inrushes are usually long interruptions in production, the loss of expensive mining equipment and enormous sanitation costs. The most severe damage is caused by unexpected, sudden inrushes of mud. In the past these caused the death of many miners.

At present the Department of Research and Development, Trbovlje-Hrastnik Coal Mine is conducting, in co-operation with the Institute for Mining Geotechnology and Environment Ljubljana, a research project entitled Criteria for Safe Mining in Areas with the Hazard of Water and Mud Inrushes. The objective of the project is to introduce the new applied method for detecting and predicting hazardous accumulations of mud and to formulate criteria for the planning and implementation of an economically effective and safe coal extraction technology.

DEFINITION OF PROBLEM

We are confronting with the problem of sudden inrushes of moist rock into mine during underground coal excavation. The formation of mud accumulations in the extraction area of the coal deposit is merely the result of its geological and tectonic structure, hydro-geological conditions and the effects of mining. These accumulations endanger mine workings, as the geomechanical processes will occasionally trigger their sudden inrush into coal pit areas during excavation works. For this reason these occurrences are ranked among dynamic processes in coal mines.

A solution to the problem of sudden inrushes of moist rock into mine is being sought in their connection with the stress-strain state of rock strata and the dynamics of muddy parts of the strata, with the goal of predicting the locations and hazard levels of eventual inrushes.

LOCATION OF COAL MINE AND MINING-GEOLOGICAL CONDITIONS

The brown coal excavated in the Brown Coal Mines of Slovenia is used for electric power generation and for general use. Of the five coal mines currently in operation, only the Trbovlje-Hrastnik Coal Mine will still operate in future and continue to exploit the Zasavje coal deposit, which has a calorific value of 12...18 GJ/t.

The brown coal deposit, which has been exploited by the Zasavje coal mines for about two hundred years, is a 16 kilometer long and approx. 2 kilometers wide region extending alongside the northern bank of the Sava River in the direction east-west. The terrain is highly diversified, with considerable differences in altitude, transverse valleys and streams gravitating toward the Zasavje valley, that is the Sava River.

The brown coal deposit was formed in the Tertiary geologic age and is characterized by a very complex geological structure and distinctive tectonics. Because of its geology and tectonics, the coal seam is characterized by extreme variations in its direction and contours, while its thickness ranges from thinning - out to some twenty or thirty meters. Coal excavation is carried out both on the surface and underground mines with depths of up to 400 m.

MINING METHOD

The coal excavation method employed in the area discussed is well-known longwall mining method. Our system of working is by retreating mining with extraction of levels from the top level to the bottom level of the coal seam together with the total caving of the roof on each level. This is in fact the sub-level caving.
Brown Coal Mines of Slovenia are famous for its difficult geological conditions but the conditions in the seam usually allow for a 200 - 300 meters-long and approx. 40 meters-wide working panel with

a height of 9 to 10 meters. The extraction of coal in the winning face, whose height is approx. 3 meters, is mechanized and carried out by means of drum sheerer. The application of the sub-level caving method enables the extraction of coal from the overhead part of the longwall face, which ensures a high mining capacity.

FACTORS INFLUENCING INRUSHES

In studying the conditions influencing water and mud inrushes, the consideration was given to the fact that the formation of hazardous accumulations of inrushing materials and the very occurrence of inrushes is influenced by several factors, which can be classified into the following main groups:

- ***rock mass;*** geological-tectonic structure of coal deposit together with the physical and mechanical characteristics of coal and surrounding rock;

- ***hydro-geological conditions;*** presence of water in the coal deposit and the hydrological characteristics of rocks;

- ***extraction technology;*** mining method, mining dynamics and geomechanical processes accompanying excavation.

The influential factors in the first two main groups stem from the actual natural conditions in the coal deposit. During investigations of natural mining-geological and hydrological conditions, we were confronted with the problem of their diversity and variability in individual coal mines, even in individual mining sections. Therefore, complex and long-lasting basic research will be necessary to determine the actual weight of individual factors. For this reason priority is given to investigations related to mining technology. The consequences of inrushes are most destructive at the face working space, where mining technology is used. Mining technology is the only subjective factor which enables the prevention of inrushes, since the other two factors stem from the given natural conditions in the deposit.

THE SYSTEM AND METHODOLOGY FOR THE PREDICTION OF HAZARDOUS OF MINE WORKINGS CAUSED BY MOISTURIZED ROCK INRUSHES

1st grade: for whole mine field

Categorization	1st category: water and mud inrushes do not occur 2nd category: water and mud inrushes are likely to occur 3rd category: permanent hazard of sudden inrushes

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2nd grade: for mining district

Predictive maps	Situation maps of the planed and realized mining works with the marking of the hazardous inrush areas and with the predictive commentaries.
Registration of Geodinamics	Measurements of pressure of rock pore water in the mining influenced area

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3rd grade: for mining block

Detection of Hazardous traps	Direct detection of locations of hazardous accumulations by means of drill holes and geophysical measurements

CATEGORIZATION OF COAL SEAM BLOCKS WITH RESPECT TO INRUSH HAZARDS

On the basis of the observed types of water and mud inrushes and a statistical analysis of their frequency, taking into account the defined criteria, the active coal mines or their parts of coal seam are classified into the following categories:

1st category: water and mud inrushes do not occur;
2nd category: water and mud inrushes are likely to occur;
3rd category: permanent hazard of sudden water and mud inrushes.

This actually involves the classification of individual mining sections with respect to the possibility and probability of water or mud inrushes from the old works, the overlying strata or from the old undue coal pillars.

PREDICTIVE MAPS OF HAZARDOUS LOCATIONS

The information on the location and extent of hazardous accumulations of inrushing materials as well as on the inrush hazard level are urgently required for the planning and execution of safe excavation works.
Temporary instructions for safe excavation in areas with the hazard of water and mud

inrushes presently contain provisions regulating the recording of data in any way related to these occurrences. Data on inrush occurrences on the upper levels is entered in the predictive map, while any local indications of potential inrushes are regularly recorded and documented in the course of mine workings.

During preparatory works in mining levels, geological engineering data and data on micro-tectonics, hydrology and other specific occurrences in the course of mining works, such as local collapses, etc., must be collected and recorded during advancement of headings (gate road). The same applies for data on all characteristics of excavation works on a particular level when the longwall face advances by retreating system.

GEOMECHANICAL MEASUREMENTS FOR PREDICTING INRUSH HAZARDS

With the objective of predicting the hazard of mud inrushes, geomechanical "in-situ" investigations are currently being conducted in the 3rd category.

Within the scope of these investigations, measuring stations equipped with stress and pore pressure cells have been set up in the mining section. We are searching for the correlations between the values obtained by the measuring stations and the collapses of masses and water invasions occurring during the advancement of the face front. The changes in rock stress and pore pressure cells are measured in dependence of face front advancement, i.e. in dependence of the distance between the face front and the measuring location, and of time.

The results of measurements already partly indicate the correlation between the anomalies in measured data and the indications at the longwall face. However, these findings are still preliminary, as they need to be supported with adequate statistical data.

DIRECT DETECTION OF LOCATIONS OF HAZARDOUS ACCUMULATIONS

An extremely important piece of information for the executors of mining works is whether hazardous accumulations of muddy materials have been formed directly in the roof area, as they represent a direct hazard to the longwall face.

The executors of mining works are currently employing a procedure for determining the indication of direct inrush hazard, which includes a system of test holes. These drill holes are used to "feel" the part of the coal pillar in front of the longwall face. The drawback of this method is that only a limited area can be covered with drill holes.

DETERMINATION OF HAZARDOUS INRUSH POINTS AT THE FACE

The studies of typical models of water and mud inrushes at the Brown Coal Mines of Slovenia have shown that, under favorable natural conditions for the formation of accumulations of inrush materials, inrushes to the face can be expected from all sides, i.e. from the roof, floor and both sidewalls. The most frequent are inrushes from the roof, and the mud represents the largest potential danger.

In longwall mining system the most dangerous inrushes are considered to be the direct inrushes of mud from the roof into the work front, i.e. the space between the face front and the hydraulic supports. This is the most critical spot as regarding the escape of workers at the time of an inrush, because there are no obstacles preventing the inrushing materials from instantaneously breaking into the working area and immediately closing the escape route.

An eventual inrush of mud into the goaf behind the hydraulic supports has less devastating consequences. The invasion of an inrushing mass into the advancing part of the mechanized front is hindered both as regards the quantity of inrushing materials and the speed of inrush by the shielding effect of the hydraulic shield supports and the tampon effect of the goaf behind the hydraulic support sections.

These findings call for the selection of adequate supports and the careful planning and execution of technological procedures enabling the prevention of mud inrushes into the front area.

TECHNICAL PROCESS FROM THE ASPECT OF INRUSH PREVENTION

From the aspect of mud inrush prevention, the careful planning and execution of technological procedures is, in addition to the natural mining-geological and hydrological conditions and adequate supports, of paramount importance.

The technological procedures used in mechanized long wall mining must be based on a knowledge of the stress-strain states in the face pillar during the advance of the face front and of the caving mechanism, and carefully adapted to the requirements in order to neutralize the hazardous effects of an eventual mud inrush.

The basic requirements for the safe execution of the technological process in mechanized longwall mining may be summarized as follows:

- face advancement must progress continuously within the limits of optimal speed as determined by the given mining/technical conditions (discontinuity is an extremely unfavorable factor);

- the technological process of long-wall mining must run continuously both as regards the face advance and coal winning from the upper section;

- the face working space should be firmly supported by the hydraulic supports of the shield type and equipped with the front support plates; any roof collapses should be prevented;

- coal extraction from the overhead part of the longwall face should be conducted behind the canopy of the hydraulic supports uninterruptedly and gradually along the entire length of the face; point extraction or pouring of coal from the roof should be avoided.

CONCLUSION

In view of the extent of their consequences, sudden inrushes of water and moist rock (mud) are ranked among the most hazardous occurrences in underground mining. These inrushes are treated as dynamic processes, as we are seeking a solution to the problem of inrushes in their connection with the stress-strain state of the rock strata or the dynamics of parts of the rock mass.

Within the scope of investigations aimed at determining the criteria for safe excavation in areas with the hazard of mud and water inrushes in the Trbovlje-Hrastnik Coal Mine, the requirements for an adequate coal extraction technology were defined from the aspect of preventing the mud inrushes into longwall face areas.
"In-situ" investigations are being conducted in 3rd-category in which there is a permanent hazard of inrushes, with the goal of acquiring the basic knowledge necessary for predicting the hazard of inrushes. We are seeking a method for the detection of hazardous "traps" of inrushing materials directly from the mine workings.