The Conceptual Method of Crosswell Seismic Reflection for Underground Coal Mine Planning in Indonesia

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Abstract

The typical problems associated with underground coal mine in Indonesia consist of the behaviour of rock mass, geological structures, underground mine support, etc. Boreholes are mainly drilled to provide the information of deposit quantity and geological structure. The presence of geological structure in underground coal mine can lead instability during development and inaccurately of deposit calculation. In complex geological structure area, it is difficult to detect fault between two adjacent exploration boreholes because those only provide excellent vertical information but very poor in lateral continuity. Therefore, the additional information between exploration boreholes is needed. The conceptual method of crosswell seismic reflection method which provides high resolution both of vertical and horizontal resolution is proposed in this study.

1. INTRODUCTION

Indonesia is a country which has potential coal resources due to its location. According to Directorate General of Mineral and Coal, total coal resources and reserves in Indonesia are 104 billions ton and 21 billions ton, respectively. Some of deposits can be mined using open pit method but others must be mined using underground method.

The economical consideration is a main decision factor to mine the deposit using surface mining, underground mining, or transition from surface mining to underground mining method. The transition method is chosen if a coal seam has significant dip, which is not economically to be mined using surface mining. Based on the social and environmental perspective, underground mine is more acceptable than surface mining.

The typical problems associated with underground coal mine in Indonesia consist of the behaviour of rock mass, geological structures, underground mine support, etc. The geological structure is the main problem that influenced the underground coal mine planning and development.

The presence of geological structure in underground coal mine can lead instability during development and inaccurately of reserves calculation. In complex geological structure area, it is difficult to detect discontinuity between two boreholes exploration because those provide excellent vertical information but very poor in lateral continuity. Therefore, the additional information between exploration boreholes is needed. The conceptual method
of crosswell seismic reflection which provides high resolution both of vertical and horizontal resolution is proposed in this study. The identification of faults, folds, washouts, seam splits and thickness changes using seismic reflection is an effective method whereby potential geological hazards can be pinpointed (Thomas, 2002).

2. UNDERGROUND COAL MINES IN INDONESIA

The principal objective in the exploration for coal is to determine the location, extent, and quality of the resources available in a particular area and to identify those geological factors which will constrain mine development (Thomas, 2002). During the exploration phase, boreholes are mainly drilled to provide the information of coal quantity and geological structure. Based on the Indonesian Standard, the borehole spacings are classified into 3 types, which correlated to geological condition. These types consist of the borehole spacing of simple geological feature, moderate, and complex geological conditions are 500 meter, 250 meter, 100 meter, respectively.

The borehole spacing provides the result in surrounding the borehole location. In a complex geological condition, it is difficult to detect small fault using the information of dense grid of boreholes. This condition will lead a hazard to stability during excavation and inaccurately of resources calculation. It means that the drilling programs only provide an approximate of geological structure interpretation between the pair drillholes.

The exploration phase is conducted to minimize the uncertainties in the next phase i.e. mine planning. Those features can be reduced by conducting the additional drilling program to locate a significant geological structures. This program is a conventional exploration program that has been used for several years. The effective exploration programs to detect geological structures can be maximized by combining drilling programs and crosswell seismic reflection. Those programs provide uncertainties risk reduction of geological structures, faster than the conventional exploration program, and less exploration cost. It is well documented that crosswell seismic reflection can be usefull to detect geological structures in exploration programs (Hawkins, et all 1987).

The information of geological structures are needed for underground coal mine design. The location of geological structures in all areas should be mapped. These features influence the type of support to be used, selection of underground mining system, and mining hazard to be prepared.

Underground coal mines in Indonesia have not been implemented and adopted professionaly although the coal deposit in Indonesia has been proved to develop potentially. There are some issues in underground coal mines in Indonesia, such as:
- the history of underground coal mines especially safety records have not been good in underground operations
- the lack of experience personnel and technology for underground coal mines
- the investment in underground mining is very high
- the weak information of coal strata and the dip of seam is very steep
- the uncessfull production of underground coal mines in the past
- the presence of the hazardous gas (such as CO) and combustible gases (such as methane)

Those issues in underground coal mines in Indonesia will be a challenge in the future. The underground mining technology should be safe and economically to gain a high extraction rate. The geological condition in surrounding of prospect area should be understood. The integration of human experience, geological condition, and technology will be the three main successfull factors in a good underground coal mining in Indonesia.

Figure 1. A typical underground coal mine in Indonesia
3. PROBLEMS IN UNDERGROUND MINE

One of major problem in underground mine is the effect of geological structures which can cause subsidence. Underground mine is associated with subsidence, which can cause damage to underground mine facilities, injury to workers, loss of productive area, groundwater problems, and main facilities problems above the ground.

![Minor geological structure in underground coal mine](image1)

The location and orientation of structural features in underground coal mine planning and development are very important. Combining with the underground face advance orientation, those characteristics will affect the potential failure possibility. It means that there is a possibility that the intersection of structural features and underground face orientation can release blocks which can fall or slide from rock mass. In tunnels excavated in jointed rock masses at relatively shallow depth, the most common types of failure are those involving wedges falling from the roof or sliding out of the sidewalls of the openings (Hoek, 2007). These wedges are formed by intersecting structural features, such as bedding planes and joints, which separate the rock mass into discrete but interlocked pieces. One or more of these wedges can fall or slide from the surface if the bounding planes are continuous or rock bridges along the discontinuities are broken (Hoek, 2007).

Groundwater inflows to underground mine can cause problems, such as operational delay, poor working area, sudden flooding, and subsidence. Most of the groundwater inflows is caused by the geological discontinuities, which provides pathways for groundwater flow (Sulistijo and Kusumo, 2012). The groundwater inflow can be controlled by dewatering or grouting method.

![Groundwater problems in underground mine](image2)

After all of exploration data have been collected, the estimation both of coal resources and reserves can be conducted. The reserves coal estimation is calculated based on the borehole data, which will give useful information
to correlate the same rock type layer. The correlation needs special consideration in complex geological structure area. The indication of small geological features, such as fault, washouts, and seam splitting, which did not detected from borehole data will lead inaccurate rock type correlation. Those geological structure will reduce the mineable reserves.

4. CONCEPTUAL METHOD

The geophysical method has been widely used in coal exploration in conjunction with borehole data, especially to delineate geological structures. The best geophysical method to detect geological structure in underground mine is crosswell seismic reflection method which provides high resolution both of vertical and horizontal resolution (Hawkins et al., 1987). This method has been developed into several variation both of source and receiver location.

The conceptual method is conducted by lowering a source in one borehole and raising the receiver in adjacent borehole simultaneously. The source is used to generate a recording signal. It is commonly used in crosswell seismic reflection either higher energy impulse, such as detonator or lower energy impulse such as air gun. The receiver is used to receive a recording signal, which is a hydrophone. Recording seismic signals by a hydrophone lowered in a borehole has the advantage i.e ambient noise and the influence of surface rayleigh waves are kept to a minimum. As they are attenuated exponentially with depth, hydrophones at appropriate depths in boreholes will therefore not record them. The reflection point will move along the reflectors between two boreholes and a reflection profile of the coal seam reflectors can be obtained (Hawkins, 1987).

It is important to recognise some of the common sources of coherent noise occuring in the recording, which consists are: direct arrivals, air waves, refractions, ground roll, tube waves, multiples, diffractions. The problems with those noise can be removed by FK filtering and other processing techniques. This process is useful for separating up going from down going waves but has the disadvantage that it can supress real events if they are not due to near horizontal
reflectors (Hawkins et al., 1987). The result of this process is the tube waves have been suppressed, meanwhile the coal seam has become visible (Hawkins et al., 1987). The reflection event only occurs with both the source and the receiver below the reflector interface. A reflector part way down the section therefore appears only a shortened length of the record section between the points where the reflector traces intersect the direct arrival hyperbola. The record sections can be migrated by expanding reflector traces which intersect the direct hyperbola to the full record width (Hawkins et al., 1987).

The second process of crosswell seismic reflection is deconvolution. The purpose of deconvolution is to compensate for filtering effects on the earth, such as those due to coal seam country rock reverberations, that complicate and inevitably broaden the simple reflection pulses from subsurface interfaces. The end product of a deconvolution operation should be reflection signals that are simple wavelets with the narrowest breadth that the earth's absorption characteristics allow (Ismail, 1988).

The third process of crosswell seismic reflection is migration. Migration is the process to move the dipping reflectors to their true subsurface positions and collapse diffractions in order to increase spatial resolution and to yield seismic image of subsurface (Yilmaz, 2001). This process can remove the effects of dip and curvature of reflectors. The migration equation enables to remove diffraction in seismic data. It is different from the normal surface seismic reflection techniques, in which downward and upward going wave are followed down through the earth from a horizontal surface.

The indication of subsurface discontinuity in seismic data can be analyzed based on its characteristics, such as travel time and amplitude. Those characteristics must be separated from seismic reflection events. The diffraction phenomena occurs when the condition of reflection wave change sharply.
After all of crosswell seismic processes are conducted and combined with borehole data, then a realistic subsurface profile can be produced. Not only the borehole data but also a surface geological map can be combined with crosswell seismic interpretation.

5. CONCLUSIONS

Underground coal mines in Indonesia have not been implemented and adopted professionally although the coal deposit in Indonesia has been proved to develop poten- tially. The typical problems that associated with underground mine in Indonesia consist of the behaviour of rock mass, geological structures, underground mine support, etc. The geological structure is the main problem that influenced the underground coal mine planning and development. The underground coal mine planning depends on a better understanding of geological information. The information of geological structure in complex areas for effective underground coal mine is not obtained only by drilling activities. Geological structures associated with the coal seam could not have been predicted from the boreholes alone. In this study, crosswell seismic reflection was proposed to detect geological structures for underground coal mine planning.

Although the present work was a conceptual method, it demonstrated the technique to detect geological structures. The correlation between borehole data and crosswell seismic reflection represent an effective methods to delineate geological structure for underground mine planning. This method is valuable in coal exploration especially in areas with large complexities.

REFERENCES

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