Vertical Integration of Underground Coal Mines with Power Plants as an Opportunity of Improvement Economic and Energy Efficiency

Introduction

In the face of electricity prices and consumption increase and crisis in Polish underground coal mining (both energy and coking) [11] the search of cost savings is necessary. In addition, Poland has to accomplish a national target for energy efficient management appointed in Law on Energy Efficiency. It also has to adapt to more radical the ESD directive. Currently, Poland has to obtain a final energy saving to 2016 in the amount of not less than 9% of the average domestic consumption of this energy in a year wherein the averaging covers the period from 2001 to 2005 [2] (under the existing Law). Energy efficiency improvements can be achieved through a number of activities, among others, modernization and reorganization of technological systems including replacement of machines and equipments for less energy-intensive. Through the optimization of production process both energy and economical efficiency is possible. During designing of construction of new mines, it is important to seek savings in deposit development design phase. In this paper the aspect of selection of optimal method of ore transportation to surface which is determined by method of deposit development and issue of optimizing the transport of coal from mine to the customer – the power plant was discussed.

Development of deposit

Development of fossil deposit consists of all actions related to connecting the deposit with surface and enabling the preparation to mining exploitation [1]. The method of development depends on many factors: geological, technical and economical, such as shape, tectonic and placement type, shape of surface, fossil resources and anticipated period of exploitation with designed annual extraction, predicted natural hazards and access to communication (roads, railways) and utilities (electric energy, water). During mine design, it is important to develop as much resources as possible and with best quality parameters with least financial costs, to enable fast construction of development headings and start of production, to ensure as small as possible cost of haulage, transport, transport of materials, drainage, ventilation and other activities necessary for the normal mining operations with a guarantee of safe and failure-free production continuity. In the Figure 1 the classification of development headings was presented. In Polish underground mines development by the shaft is the most popular. These excavations are characterized by a cross-section over 4 m² and a significant depth, they are drilled usually using explosives. A transport of ore to the surface is realized by skip which is extraction vessel moving in the shaft using carrying and balance ropes.

The decline is an alternative for shaft deposit development. It is narrow working inclined at 45°, in which fossil is transported to surface on conveyor belt. In polish coal mines this method is not popular, currently there are only three mines using it: KWK “Marcel”, KWK “Janina” and ZG “Siltech”. On contrary, in Australia only one mine is based on shaft – the rest use decline [9]. The main reason for that

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Shaft was the only considered solution. Building of first Polish decline – “Janeczka”, was started in 1993, during restructuring of Polish coal mining industry. Other reason may be the difference in mining-geological conditions.

Choosing optimal development method

Important issue of design process of mine is choosing development method – shaft or decline, considering costs of investment and maintenance, also operating costs of transport of ore to surface and electrical energy usage. To achieve this goal, a JAVA program was written based of author's method.

The program consists of three tabs. In tab “Input data” (Fig. 2) user provides input parameters, such as:

- depth of deposit
- whether decline would use car transport (this determines inclination angle)
- planned daily coal production
- costs of building and equipping both considered excavations
- costs of running excavations and devices used to transport ore to surface
- energy intensity of used transport devices in both cases
- costs of electricity
- number of working day in a year
After providing needed data, the program calculates and returns parameters necessary to choose suitable method of excavation (Fig. 3), (without taking into account amortization costs – this feature will be part of next version of program) such as:

- length of decline,
- device efficiency in both cases,
- total build and equipment costs and costs of annual running of excavation,
- energy usage.

The tab “Charts” summarizes those parameter for both methods. When considering improving energy efficiency the chart comparing the energy usage is crucial, since electricity costs are significant part of total costs.
Diagram showing total costs of both decline and shaft should help the designer to choose optimal method. Preliminary calculations and examples around the world lead to conclusion, that in many cases decline is beneficial considering both investment costs and energy usage.
Vertical integration of mine and power plant

The advantage of decline, besides low build and transportation of ore to surface costs, is the possibility of coal mine with power plant, like for example KWB “Belchatów” lignite and Power Plant “Belchatów”. There are many aspects of this solution, such as:
• economical
• organizational
• political
• ecological

In this article authors have focused on aspects: economical related to reduction of costs of coal transportation, and ecological related to reduction of energy usage. Organizational and political aspects were thoroughly described in case of integration open pit lignite mines with electricity manufacturers in publications [4, 5]. In authors' opinion this issue of cooperation is very similar.

Main idea of vertical integration is adjacency of power plant and mine, so that coal transportation to the consumer can be based on conveyor belt through the decline. This solution, contrary to ore transport by shaft, considering its nature, provides constant flow of coal and ensures its delivery. Example of this set in Poland are KWK “Siersza” in Trzebinia (built in 1949 [3]) integrated with Power Plant “Siersza”. In 1974 the decline “Czech” was built as main line connecting the power plant with underground part of mine. In its top moment in 1988 the decline transported 120 000 Mg of coal per day, until 1996, when this value decreased to 50 000 Mg per day [3]. In 1999 KWK “Siersza” was wound up under normal insolvency proceedings, but Power Plant “Siersza” in still operational as part of Tauron Wytwarzanie S.A.

Important aspect of vertical integration in given example is possibility of abandoning railway transport of coal so it would be transported by conveyor belt. Main advantages of this solution are:
• reduction of electricity used by trains, thus reduction of CO2 emission
• reduction of air dustiness
• elimination of danger of self-heating of coal and endogenic fire of coal mounds
• reduction of coal losses during transport
• reduction of coal prices due to lower transport costs

Transport cost reduction is effect of using less energy intensive method of transportation of ore to surface (on conveyor belts) and abandoning railway transport. In Poland in 2013 the biggest coal consumer was energy sector, which has used 53% of total coal production [7]. On grounds of layout of mines and power plants, coal often must be transported over long distances. Average distance in 2010 was 186 km and has increased since 2006 by 64km, showing increase tendency [6]. The biggest railway companies in Poland are: PKP Group, DB Schenker Rail Polska S.A. and CTL Logistics Sp z o.o. Their transport part of coal in 2010 was accordingly: 60%, 70% and 50% of all cargo [6]. To estimate the share of transport costs in coal price, the prices of culm assortments with excise from Kompania Węglowa S.A., by the pricelist effective from 1st of January 2014 [8], while transport costs were based on basic price table for 25 Mg cargo in biaxial carriage effective from 1st of January 2013 [10]. Analysis was performed for distances: 50, 100, 150, 200, 250, 300, 350, 400, and 500 km. The Table 1 shows the share of transport costs in price of 1 Mg of culm assortment coal for individual caloric values and transport distance.
Tab. 1. Comparison of the transport cost of coal unit price of 1 Mg of culm assortments coal

<table>
<thead>
<tr>
<th>Qir [MJ/kg]</th>
<th>Transport distances [km]</th>
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<tbody>
<tr>
<td></td>
<td>50</td>
</tr>
<tr>
<td>21</td>
<td>16.4%</td>
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<tr>
<td>22</td>
<td>15.2%</td>
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<td>23</td>
<td>14.1%</td>
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<td>24</td>
<td>13.2%</td>
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<tr>
<td>25</td>
<td>12.4%</td>
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<td>26</td>
<td>11.7%</td>
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<td>27</td>
<td>11.0%</td>
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<td>28</td>
<td>10.5%</td>
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<tr>
<td>29</td>
<td>10.0%</td>
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<tr>
<td>30</td>
<td>9.5%</td>
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<tr>
<td>31</td>
<td>9.1%</td>
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Source: own study based on [8,10]

The analysis does not take into account the possibility of transportation discount. Thus, for coal with caloric value of 21 MJ/kg transported over 400 km distance, the unit price of 1 Mg is 306.19 PLN, including transport costs of 160.36 PLN. The results lead to conclusion, that transportation cost is significant share of unit price of 1 Mg of coal – as shown in Table 1, in case distance longer than 400 km and lower caloric value it is over 50%.

Summary

In this article two methods of deposit development were presented: shaft and decline. Authors’ method of choosing optimal one was also presented. Given example was performed in created program and showed, that decline can be less energy intensive and cheaper alternative for shaft.

In the second part of article, the issue of vertical integration of coal mines and power plants was raised. This solution has numerous advantages, such as possibility of shortening the distance between coal supplier and recipient and significant reduction of transportation costs. Then, analyze of coal transportation to recipient has been made and led to conclusion that transport costs are big part of end unit cost of coal, dependent on caloric value and distance. Therefore, it is crucial to provide constant coal delivery, which is easy when using direct transport through decline.

Abstract

In the article a problem of optimal choice of deposit development method considering the economic and energy efficiency was described. The incline was presented as an alternative to the shaft. In the paper an original method and a program created in JAVA which allows to specify a more favorable deposit development method for selected parameters was presented. The issue of vertical integration system an underground coal mine – a power plant was discussed. Attention is paid to the costs of transportation of coal from the mine to the power plants.

Keywords: optimization of production, underground mining
Streszczenie


Słowa kluczowe: optymalizacja produkcji, górnictwo podziemne

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