Research on mining cost of coalbed methane based on activity management
——Field study of mining with pressure-releasing in Yangquan minefield
Zheng Ai-hua\textsuperscript{a,b,*}, Zheng Xiao-hua\textsuperscript{b}, Xu Jia-lin\textsuperscript{a,c}, Wu Ren-lun\textsuperscript{a,c}
\textsuperscript{*State Key Laboratory of Coal Resources and Mine Safety, Xuzhou 221008, China}
\textsuperscript{bSchool of Management, China University of Mining & Technology, Xuzhou 221116, China}
\textsuperscript{cSchool of Mining Engineering, China University of Mining & Technology, Xuzhou 221116, China}

Abstract

Recently, on the background of energy-saving and emission reduction, coalbed methane (CBM) as an important new type of clean energy is paid more and more attention to. However, the current research mainly focuses on the technology level of CBM mining, and the research on mining cost and other economic evaluation has been absent, which is a disadvantage for industrialization of the CBM resources. In this paper, the cost of CBM mining with pressure-releasing in Yangquan minefield was investigated and analyzed through spot investigation firstly, and the advanced activity-based cost management (ABM) was implanted. The results show that the mining cost of CBM structure is closely related with the activity-based cost driver, and the correct division of the activity-based cost driver is the key to accurate cost measurement. Through comparing the mining cost of No. 3 Mine with that of No.5 Mine, it is found that there is a significant effect of mining method, mining technology, and the exploitation time on the mining cost of CBM. The research not only has laid a foundation for the analysis about mining cost level, composition and influencing factors, but also provided the basis for the government to make the relevant economic policy of CBM mining project.

Keywords: ABM; CBM; pressure-releasing mining; green mining

1. Introduction

For a long time, the gas (commonly known as CBM) has been considered as “the first killer” of coal mines, so the pump for drawing gas becomes a chief premise for safety production. The studying team led by Academician QIAN Ming-gao researched the serious environmental problems caused by coal mining and developed the concept of green mining for a long run. Whereas, the co-mining of coal and gas as one branch of green mining technical systems, whose purpose is to realize the transition from security-aimed passive mining to resources deep recycling-aimed active mining, is the exploitation of both coal and CBM in coal seams as resources of coal mines.

In the passive mining, CBM leaks into the atmosphere along with coal mining, aggravating the global greenhouse. But in resources deep recycling-aimed active mining, CBM is a new type of clean energy that releases high heat with no pollution. Our country possesses the third reserves of CBM resources in the world, if CBM can be mined and used reasonably, it will not only enhance the safety of coal mining, decrease the waste of CBM resources, but also have realistic and profound significance in improving the energy structure, reducing the CBM disaster, increasing the production efficiency and economic benefits, ameliorating the living environment of the mining area and the quality of life, promoting the sustainable development of mining area and surrounding areas, and protecting the atmospheric environment\textsuperscript{11}. At the same time, on the background of global energy-saving and emission reduction, using CBM reasonably and efficiently is beneficial to the enhancement of the national image.

2. The research significance of gas mining cost

According to the model of mine production and industry chain, mine production is still the main part of coal mining, and the CBM hasn’t yet been a single product, nor industrialization. Though the technology system of co-mining of coal and gas has
been proposed, because the lack of the combination of technical and economic management, there are still many constraints for the development of CBM industrialization. Therefore, the critical factor of CBM industrialization development is implementation of the research on economic evaluation of CBM development and utilization. The mining cost is not only the most basic data in economic evaluation, but also the main contents of it.

2.1. Theoretical significance

(1) Providing basic information for carrying out the economic evaluation of CBM comprehensively. At present, the mining cost of CBM hasn’t stripped out from raw coal cost. On the one hand, it makes economic evaluation of CBM project face big difficulties; on the other hand, for the mining enterprises, they can’t master the level of mining cost, which makes the cost management and control become fantastic talk. Therefore, the cost research is significant to the research of economic evaluation and cost management of mining enterprises.

(2) Laying a foundation for analyzing the division of activity-based cost driver, the composition and the influence factors of CBM mining cost, and establishing a platform for economic evaluation. In this paper, firstly through field study, the advanced ABM was implanted into Yangquan minefield, combined with the technical features of pressure-releasing CBM mining. The process of activity and the activity drivers were analyzed, and then the activity-based cost pools were built. At the same time, the influencing factors were anatomized, such as the mining technology, the exploitation time (which is referred to the time that the coal has been mined), and so on. The research not only provides ideas for stripping out CBM mining cost from raw coal cost, but also lays a foundation for the research of CBM mining cost, simultaneously establishing a platform for economic evaluation based on ABM. This not only has a positive guiding significance for mining and using CBM in Yangquan minefield, but also provides reference for economic researches about mining and using CBM in other mining enterprises.

2.2. Practical significance

(1) Providing an operational platform for CBM costs collecting and stripping. The research on mining cost of CBM has been done little in China, whereas it is included in the raw coal cost, and makes the CBM become a kind of by-product. What we mainly do in this paper is stripping the CBM cost from raw coal cost according to the mining drivers of CBM, and regarding the economic value of CBM as an independent product, which provides an operational platform for coal enterprises to compute CBM cost in practice, and gives an important reference for coal enterprises to strengthen cost management and also develop and utilize the CBM in the future.

(2) Providing evidence for the government to formulate policies related industries. The development of CBM requires large investment, and has high technical difficulty and high risk, so it needs the national support and help. When formulating industrial policies, the actual mining cost of CBM can help the government make pertinence policies, which not only can full play the incentive of policies, but also make the policies be better targeted. Therefore, the findings of this research provide the basis for the government to make the relevant policies of CBM mining project, advance the CBM industrialization, as well as provide an extensive space for the economic evaluation of CBM for further research.

3. The description of mining with pressure-release

CBM, mainly as a status of absorption, is a kind of gas that is generated and stored in the coal seam and surrounding terranes, which is mixed with methane and others. The air permeability of CBM reflects the difficult degree of CBM mining and also decides the way of mining. In China, there are two main ways for CBM mining, one is pre-drainage, which is suitable for the coal seam with high air permeability; the other is pressure-release, which is strata movement caused by coal-rock mining. The way can enlarge the low permeability coal seam tens of times to hundreds of times through pressure-release of coal seam\textsuperscript{[2]}. More than 70% of coal seams belong to comparatively difficult to drain\textsuperscript{[3]}, therefore, mining with pressure-releasing becomes an important way of CBM mining in China.

The mining of pressure-releasing is used in Yangquan minefield, and its mining technology is showed in Figure 1.
4. Research on mining cost of CBM based on activity-based management

4.1. The implication of ABM

ABM is a new type of management concept of modern enterprises, and an extension of in-depth activity-based cost (ABC) \[^4\]. Its metering means of cost is ABC, and through penetrating into operating level of the production and management process of enterprises, the product costs contact with the resources consumption by activity directly, namely product is completed by a series of activities, and the cost of product is constituted by the resources that is consumed by the activities which are necessary to complete the product, thus reveals the internal mechanism of cost formation, links enterprise management activities with cost control finally, and provides a scientific method for improving the management efficiency and competitiveness of enterprises.

4.2. Study on the CBM mining cost with pressure-release

As is shown in Fig.1, through the movement of terranes, CBM is accumulated in the high level suction roadway firstly, and then goes into pumping stations through mining pipeline by the mining sector. These constitute the necessary activities of CBM mining, till then the CBM mining process from underground to surface is completely finished. The mining flow of CBM is as follows:

High level suction roadway ➔ Mining pipeline ➔ Mining sector ➔ Pumping stations.

(1) Components of activity drivers

The activity cost of CBM project occurs when developing and utilizing the CBM. Therefore, the mining cost should be ascribed to the CBM. And so, the cost of CBM mining is composed of the digging cost of high level suction roadway, the laying cost of pipeline, the running cost of mining sector and pumping stations. For the CBM mining is multi-step, the activities of mining should be allocated to different cost pools, so that the process of CBM mining can be partitioned into four activity-based driver pools: the digging cost of high level suction roadway, the laying cost of pipeline, the mining sector cost and the pumping stations cost. Correspondingly, activity-based drivers are the digging footage of high level suction roadway, the laying length of pipeline, the drainage quantity of mining sector, and the running time of pumping stations. The composition of activity-based drivers of CBM mining is shown in Figure 2 concretely.

(2) Composition of ABC

The cost items included in each activity are important data that are collected in the field, and also are necessary data for economic evaluation. For example, the digging cost of high level suction roadway mainly includes primary materials, staff wages, welfares cost, depreciation cost, power expenses, repair cost, leasing cost; while the running cost of mining sector mainly includes primary materials, staff wages, welfares cost, power expenses, depreciation cost and other expenditures and so on. By site investigation, the mining cost of CBM is stripped from raw coal cost seriatim according to mining activities.

5. Field study of CBM mining cost with pressure-releasing in Yangquan minefield

The research on the mining cost of CBM in this paper is taken Yangquan minefield in Shanxi province for example. In the process of spot investigation, we take the third mine and the fifth mine in Yangquan as the research objects.
5.1. The composition of mining with pressure-releasing cost in Yangquan minefield

According to the principle of activity driver, we stripped the CBM mining cost from the raw coal cost of the third mine and the fifth mine, arranged, and gathered, in the light of the detail cost items in the raw coal cost table, which is shown in Table 1 concretely.

Table 1. The actual cost structure of the third mine & the fifth mine (Unit: 10^4 yuan)

<table>
<thead>
<tr>
<th>The activity-based cost pools</th>
<th>The third mine</th>
<th>The fifth mine</th>
</tr>
</thead>
<tbody>
<tr>
<td>Digging cost of high level suction roadway</td>
<td>573.46</td>
<td>860.22</td>
</tr>
<tr>
<td>Cost of pumping stations</td>
<td>70.31</td>
<td>172.4</td>
</tr>
<tr>
<td>Laying cost of pipeline</td>
<td>413.87</td>
<td>743.19</td>
</tr>
<tr>
<td>Cost of mining sector</td>
<td>135.7018</td>
<td>47.9845</td>
</tr>
<tr>
<td>Total</td>
<td>1193.3418</td>
<td>1823.7945</td>
</tr>
<tr>
<td>The CBM mining volume (10^4 m^3)</td>
<td>3020.81</td>
<td>8001.34</td>
</tr>
<tr>
<td>The unit cost of the CBM mining (yuan/m^3)</td>
<td>0.395</td>
<td>0.2279</td>
</tr>
</tbody>
</table>

From Table 1, we can see that the unit cost and the volume of the CBM mining both fluctuate comparatively large in each year of the third mine. By observing each cost pool, we can see that there was a large increase in the running cost of pumping stations and the laying cost of pipeline from 2005 to 2006, while the running cost of mining sector decreased significantly. In addition, another main reason causing the mining cost change is the CBM mining volume difference, which was 2.6 times in 2006 of that in 2005, leading to the result that the unit cost of the CBM mining in 2005 was nearly 2 times more than that in 2006. While the most important reason causing that the unit cost of the CBM mining was raised from 0.23 yuan in 2006 to 0.43 yuan in 2007 is that the digging cost of high level suction roadway was raised from 8,602.2 thousand in 2006 to 17,153.5 thousand in 2007 which is twice of that in 2006; and another main reason is the laying cost of pipeline was raised from 7,431.9 thousand in 2006 to 10,789.3 thousand in 2007; in addition, under the condition of cost leaping, the CBM mining volume hadn’t been increased, but decreased by 11.5%, as a result, the unit cost of the CBM mining was raised 0.2 yuan.

While the data of the fifth mine in each year were relatively stable, all the cost pools had little fluctuation, in addition, the CBM mining volume was also very stable, so the unit cost of the CBM mining was kept 0.22 yuan or so. We can see that the operation in the new mine is very stable.

5.2. Analysis of influencing factors

Through further analysis investigation and research, we find that there are two main reasons: first, the exploitation time (time factors) is different; second, the previous mining technology (technical factors) is different.

(1) The difference caused by time factors

The third mine is an old mine with nearly 60-year mining history, and the recoverable reserves are 133 million tons, the accumulated coal production is 169 million tons. For this over-age service mine, the mining has great difficulties, so the CBM volume will be also decreased, some related information shows that the average CBM mining volume of each coal ton in 3 years is only 11.55m^3/t; while the fifth mine was established in 1984, only with more than 20 years mining history, the mining of this maturity period mine is relatively easier and the CBM mining volume is relatively bigger, and the average CBM mining volume of each coal ton in 3 years is 28.89m^3/t. The CBM mining volume of each coal ton of the third mine is inferior to the fifth mine, i.e. nearly 1/3 of the fifth mine. Therefore, the unit cost of the CBM mining is higher in the third mine.

(2) The difference caused by technical factors

Another factor is the previous mining technology. For the third aging mine, the mining method is from up to down in the past, and the working face is in a relatively deep location at present. When mining the deep mine seam, the CBM that is included in the coal seam above has released much in the process of mining the coal seam above, as a result, at present, in the process of mining,, the CBM can’t be collected so much; while the fifth mine is different as a new mine. In contrary, the mining method is from down to up, a lot of CBM that is included in the coal seam above can be released in the process of mining coal seam below, and the fifth mine is in the boom period, so lots of CBM can be released in the process of mining, as a result, the CBM mining volume of each coal ton is larger and the unit cost is lower.

6. Conclusions

1) The cost research of CBM development and utilization, not only can carry out the economic evaluation of it, make clear the weak economy of the CBM mining, and pay attention to the environmental value and resource value of the CBM, but also can
help us to understand the CBM mechanism adequately, which makes it convenient to extend the implementation of green financing.

2) Through analysis, we master the present level of CBM mining cost and analyze the influence of technical factors and time factors on the mining cost, and also provide a reference for the cost research of development and utilization of CBM in other coal mines. But it is noteworthy that the mining technologies of CBM are diversiform in our country, the mining costs are different with the different mining technologies, and the accounting of cost elements should conform to the requirements of cost drivers.

Acknowledgements

Financial support for this work, provided by the open-end fund from State Key Laboratory of Coal Resources and Mine Safety, is gratefully acknowledged.

References