Strategies for Highly-Efficient Recovery of Coal Resources in China

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Abstract: Since entering the new century, China’s coal industry has witnessed the rapid development, and provided a reliable energy supply for the national economic and social development. But after the “golden decade” of rapid development, the coal industry now is facing overcapacity, low industrial concentration and production efficiency, high pressure of production safety and environmental protection and other prominent issues. Based on defining the connotation of highly-efficient recovery of coal resources, this paper established the relevant 8 indicators to reflect the highly-efficient recovery level of coal resources, summarized the present situation of China's coal resources recovery and the main problems, analyzed the development environment of China's coal industry under the new situation, and finally put forward the strategic measures to promote highly-efficient recovery of coal resources in China.

Keywords: coal resources, highly-efficient recovery, development environment, strategic measures

1. Background

Coal is the main energy in China. Since entering the new century, China's coal industry has made significant progress, and the level of production safety, resource recovery rate and mining mechanization increased significantly, which provided a reliable energy supply for the rapid development of the national economy. However, due to the changes of China's economic environment, slow growth of energy demand and other factors, some prominent contradictions in the coal industry have significantly restricted the healthy development of the industry.

The first problem is serious overcapacity. In the past few years, 16 industries including coal, electric power, chemical and others have invested in coal mines. It is reported (Han 2016) that only during the nine years from 2005 to 2014, the fixed assets of coal industry increased totally more than 3.3 trillion RMB, which brought a large number of production capacity. Affected by the slowdown of economic growth and energy structure adjustment, Chinese coal demand has reached the peak platform and caused the overcapacity of coal supply, so shutting down the backward capacity is the most important task in the future.

The second problem is the low efficiency of coal production. There are about 4.3 million coal mine workers in China, and the annual coal production per capita is less than 900 tons, while it was reported (EIA 2016) that the annual production per capita in the United States is more than 10 thousand tons.

The third problem is that the green coal resources are not rich. Among the 1.53 trillion tons proven reserves, only about one third are green coal resources in accordance with the principle of "safety, technology, environment and economy". The coal resources with high quality and easily mining conditions are not abundant.

The fourth problem is the unreasonable structure of coal mine production capacity. About 90 percent of coal mines in China are small mines, most of which have not yet realized mining mechanization with a low recovery rate of 30 percent and high incidence of accidents. Under this background, it is of great strategic significance to promote the coal industry structure adjustment and upgrading through studying the strategic measures of the highly-efficient recovery of coal resources in China.

2. Connotation of Highly-efficient Recovery of Coal Resources

2.1 Connotation of highly-efficient coal recovery

Highly-efficient recovery of coal resources in this study refers to a broad concept, which can be described as follows. Coal mine is constructed based on green resource which conforms to the principles of "safety, technology, environment and economy", with advanced mining methods and technical equipment adopted to improve production efficiency and resource recovery rate on the premise of safety guarantee, minimize the disturbance on ecological environment, and finally achieve the coordinated development of resources, environment, economy and society.

2.2 Indicators of highly-efficient coal recovery level

It is reported (Hao and Ren 2015) that indicators should be established with the principles of representativeness, independence and quantification. According to the characteristics of the coal industry, combined with the connotation of highly-efficient recovery of coal resources, 8 indicators are selected from the four aspects of safety,
efficiency, recovery and environment to reflect the highly efficient level of coal resources recovery. The specific indicators and significance are shown in Table 1.

Table 1. Representative indicators of highly-efficient coal recovery.

<table>
<thead>
<tr>
<th>Four aspects</th>
<th>Specific indicators</th>
</tr>
</thead>
<tbody>
<tr>
<td>Mining safety</td>
<td>Death rate per million tons</td>
</tr>
<tr>
<td>Mining efficiency</td>
<td>Mining mechanization level, coal mining efficiency</td>
</tr>
<tr>
<td>Resource recovery</td>
<td>Coal recovery</td>
</tr>
<tr>
<td>Environmental protection</td>
<td>Mining area rehabilitation, Wastes standard discharge</td>
</tr>
</tbody>
</table>

3. Present Situation and Existing Problems of Highly-Efficient Recovery of Coal Resources in China

3.1 Present situation of coal resources recovery

3.1.1 Geological conditions of coal resources

According to the statistics of Ministry of Land and Resources, there were 1.53 trillion tons of proved coal reserves in 2014. In accordance with the international practice, China's proven coal reserves amounted to about 168 billion tons, which makes China rank the third in the world after the United States and Russia, but the per capita occupation is only about half of the world average.

On the basis of the research results in the major projects of China Academy of Engineering, coal reserves in the northern area of Kunlun Mountains-Qinling Mountains-Dabie Mountains account for 92 percent of China, mainly concentrated in Shanxi, Shaanxi, Inner Mongolia, Ningxia, Xinjiang provinces; and the southern area of Kunlun Mountains-Qinling Mountains-Dabie Mountains only 8 percent, mainly concentrated in Guizhou and Yunnan provinces. Proven reserves in economically developed eastern region account for less than 6 percent of the country, while the reserves in the relatively backward western region account for more than 94 percent. It was reported (Xie et al 2014) that the reverse distribution of coal resources and economy could make the West speed up the pace of coal mining.

3.1.2 Coal mines’ production capacity

According to the data from the National Coal Supervision Bureau, as of the end of 2014, there were about 11 thousand coal mines in China with the total coal capacity of about 5.4 billion tons/year, of which about 4.6 billion tons/year was on production, and about 800 million tons/year under construction. Among the total capacity of 5.4 billion tons/year, there were 1100 large coal mines with the capacity of about 3.3 billion tons/year, 1800 medium-sized coal mines with the capacity of about 1.2 billion tons/year, 8000 small coal mines with the capacity of about 900 million tons/year.

In 2014, China produced 3.87 billion tons coal, with consumption 4.11 billion tons, and net import 285 million tons. The production of about 970 large coal mines with an annual capacity more than 1.2 million tons accounted for 66.5 percent of China's total. Of the 970 large coal mines, 53 were super large mines with an annual capacity of more than 10 million tons, whose production accounted for 18 percent of China's total. Production of raw coal in Shanxi, Inner Mongolia, Ningxia and Gansu provinces accounted for two thirds of the whole country.

3.1.3 Overall situation of highly-efficient recovery level of China's coal resources

Based on systematic research, the main indicators of highly-efficient recovery of coal resources in China, the United States and Australia are contrasted as shown in Table 2.

Table 2. Comparison of main highly-efficient coal recovery indicators among China, the United States and Australia.

<table>
<thead>
<tr>
<th>Main indicators</th>
<th>Inner Mongolia</th>
<th>Average in China</th>
<th>Average in the US</th>
<th>Average in the AU</th>
</tr>
</thead>
<tbody>
<tr>
<td>Death rate per million tons (%)</td>
<td>0.027</td>
<td>0.255</td>
<td>0.018</td>
<td>0.005</td>
</tr>
<tr>
<td>Mining mechanization level (%)</td>
<td>100</td>
<td>Large Co.:95</td>
<td>100</td>
<td>100</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small &amp; medium Co.:30</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal mining efficiency (tons annual)</td>
<td>6500</td>
<td>Large Co.:2600</td>
<td>12000</td>
<td>13800</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small &amp; medium Co.: 500</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal resources recovery (%)</td>
<td>85</td>
<td>Large Co.:75</td>
<td>79</td>
<td>-</td>
</tr>
<tr>
<td></td>
<td></td>
<td>Small &amp; medium Co.: 40</td>
<td></td>
<td></td>
</tr>
<tr>
<td>Coal industry concentration (Top four , %)</td>
<td>40</td>
<td>25</td>
<td>50</td>
<td>48.7</td>
</tr>
<tr>
<td>Environmental protection</td>
<td>Large Co. meeting the standard</td>
<td>Part of large Co. meeting the standard</td>
<td>Generally meeting the standard</td>
<td>Generally meeting the standard</td>
</tr>
</tbody>
</table>

Through the comparative analysis of these indicators above, it can be seen that the development of highly-efficient recovery of coal resources is not balanced in different regions and different scale enterprises. From the scale, comparing with the small and medium-sized coal enterprises, large enterprises have a higher efficient recovery level on mining machinery, coal production efficiency, coal recovery rate and other indicators. From the
scale, comparing with the small and medium-sized coal enterprises, large enterprises have a higher efficient recovery level on mining machinery, coal production efficiency, coal recovery rate and other indicators. From the areas, the Inner Mongolia Autonomous Region with the largest coal enterprises is in a leading position in highly-efficient recovery level, mining mechanization, production efficiency and resource recovery rate in China. Except slightly lacking of environmental protection, it was reported that the efficient recovery level of Inner Mongolia had little difference with the United States and Australia. But as a whole, compared with the United States, Australia and other developed countries, there is still a large gap on the highly-efficient coal recovery level in China on the aspects of mining mechanization, coal production efficiency, the death rate per million tons, coal industry concentration and environmental protection.

3.2 Main problems of coal resources recovery

Based on the analysis above, it is found that there are some main problems of coal industry in China nowadays.

(1) Serious overcapacity. Compared with coal demand, China’s coal production capacity has reached an excess of about 750 million tons/year, and coal mine capacity under construction is 800 million tons/year, which means China’s coal production capacity is ahead of coal demand seriously. Most coal mining enterprises have been in the red caused by the overcapacity. And the whole coal industry has fallen into an unprecedented predicament.

(2) Overall complicated exploitation conditions. China’s coal resources are deeply buried with complex geologic structure and serious disasters, and the mining technical conditions belong to the middle and lower level in the world. Among the total mines, 70-75 percent are troubled by bad mining conditions. The coal mining conditions in Shanxi, Shaanxi, Inner Mongolia, Gansu, Ningxia and Xinjiang provinces are relatively simple, but the mining conditions in most coal production regions of China is poor and harsh. Mainly affected by this restriction, there are still more than 5000 non-mechanized coal mines in China, most of which have low capacity and bad safety conditions.

(3) Relatively low mining efficiency. There are more than 4 million employees in China’s coal industry, while it was reported (Teng et al 2017) that the number was only about 80 thousand in the United States and even less in Australia (Reported by Wood Mackenzie 2015). Annual coal output per capita in Australia and the United States is more than 10 thousand tons, which is 10 times the average level of China, nearly 4 times of China’s large coal enterprises, 2 times of China’s highest efficiency region, and 1.8 times of the highest efficiency enterprise (Shendong). Especially, China’s old state-owned coal enterprises have a historically heavy burden and undertake the social functions in different degrees.

(4) Much pressure of safe production and environmental protection. It was reported (Yuan 2016) that a considerable part of coal mines faced the geological disasters and the fundamental management needed to be strengthened, so the safety situation of coal production remained severe. The mining subsidence area amounted to 1 million hectares with the annual added area of about 60 thousand hectares, especially the plain area in Middle East of China, such as Hebei, Shandong, Henan, Anhui, Jiangsu, and Liaoning. Subsidence areas are usually used as farmland, which caused the prominent contradiction between farming and mining.

4. Development Environment of Coal Industry in China

After the rapid development of golden decade (2002-2011), China’s coal industry has entered into a period with deep adjustment, and the development environment of the coal industry has undergone fundamental changes.

Firstly, from a global perspective, the oversupply of coal market is a long-term trend, and the consumption trend of low-carbon energy has an important effect on the coal demand. China’s economy has entered into a new normal with slow growth of energy demand, coupled with the national development of non-fossil energy and natural gas, which would limit the total coal consumption and its growth. It was reported (Li and Zeng 2014) that coal demand in China had entered into the Peak Platform Area.

Secondly, it was reported (Li 2013) that in the past the domestic coal market was constrained by the transportation channel, but now the bottleneck of coal transportation from north to south and from west to east has been broken. Railway transportation becomes abundant, which has provided the condition for the eastern and southern regions to reduce capacity. Meanwhile, as the transportation cost decreased, it would further improve the competitiveness of coal production in the western area. So coal industry in the whole country would face more intense competition.

Thirdly, China’s coal market will always be impacted by imported coal for quite a long time in the future. The cutting down of China’s domestic production capacity would likely to cause the rebound of domestic coal price, by when international coal from Australia, Indonesia and other countries flooding to China would once again impact the domestic market. The foreign coal is always a "Damocles Sword" hanging on Chinese coal market.

The above situation will force China’s coal industry to consider the future development with a broader vision and a higher perspective. Although highly-efficient coal recovery is not a new proposition, but for China’s coal industry now and in the future, it is much more important than ever before.

5. Strategic Measures for Highly-efficient Recovery of Coal Resources in China

Based on the above analysis, this paper put forward the strategic measures for highly-efficient recovery of coal resources in China.

(1) China should give full play to the advantages of green coal resources and optimize coal mines’ development layout based on coal imports. Australia, Indonesia and other countries have the great potential for coal development and competitive advantage for coal export to China. It could be predicted that China’s coal imports in the future will remain...
100 million tons. Combing with coal resources distribution of the main coal production areas, China should understand this situation and optimize the development layout of coal mining. Coal reserves in Shanxi, Shaanxi, Inner Mongolia, Gansu and Ningxia provinces are mainly green resources, with the potential coal production reaching 3 billion tons/year. Coal mining industry should continue to concentrate on this area before 2050. And the comprehensive energy base status of this region should be further highlighted by stabilizing and increasing the exploiting scale according to the demand. In Northeast and Southern China, the geological conditions of coal resource are complex with poor mining conditions; Also in East China, due to a long history of mining, easy mining resources in the shallow ground were exhausted and the remaining resources in the deep are affected by the threat of disasters, so mining in these areas should be restricted, and the exploiting scale and production capacity should be cut down in the next few years. And in the long term, coal mining in the East would be dropped out before 2050. Xinjiang is rich in coal resources with relatively good mining conditions, but due to the distance from the mainland market, coal mining in this area should mainly be positioned to meet the needs of the region itself in a longer period. Qinghai should limit the coal development to protect the ecological environment.

(2) China should enhance overcapacity reduction, achieve balance between supply and demand and improve the highly-efficient recovery level. At present, coal production in the whole China is generally overcapacity, but the focus of overcapacity reduction lies in the Northeast, East and Southern China. Coal mines with backward mining technology, low production security, poor quality and serious environmental damage and heavy losses should gradually be eliminated. Through shutting down the illegal production capacity, checking capacity by adjusting work regulation and postponing or suspending the projects under constructed, China would achieve the balance between coal production and demand. The focus of overcapacity reduction should be distinguished among the different coal production areas. For Northeast and East China, coal mines with backward capacity (non-mechanized mining), insecure mining conditions and serious loss should be eliminated. In Sichuan, Chongqing, Hunan and Hubei provinces of East China, coal mines should mainly be closed gradually. And in Yunnan and Guizhou provinces, the capacity should mainly be determined to meet the demand of these two regions by the measures of shutting down some mines then reforming some by technology. In Shanxi, Shaanxi, Inner Mongolia, Gansu and Ningxia provinces, the key point of overcapacity reduction is to propose and suspend some mines under construction, and shut down then reform some mines by technology. In Xinjiang and Qinghai provinces, coal capacity should mainly meet the region’s demand, by proposing and suspending some mines under construction, and shutting down then reforming some mines by technology. According to the characteristics of coal resources and coal production in different regions, shutting down, restructuring and reforming coal mines should be taken to reduce overcapacity, optimize coal production structure and enhance the highly-efficient recovery level of coal resource comprehensively.

(3) China should expand the advanced experience and adopt the advanced technology and equipment to promote highly-efficient recovery. The advanced experience of Shendong and Huainan mining area should be vigorously promoted and the application of advanced mining technology and equipment also should be expanded based on geological conditions of resources to improve highly-efficient recovery level of coal resources. In Shanxi, Shaanxi, Inner Mongolia, Ningxia and Xinjiang provinces, super large modern mines with 10 million tons’ capacity should be constructed in terms of one working face or not more than two in one coal mine with advanced mining technology, first-class equipment, reliable security, high resource recovery and excellent environment. In Xinjiang area, with the suitable resources and environmental conditions, the world class open mine could be constructed with priority. In East, Northeast and Southern China and other regions, the existing mines should promote technology innovation and advanced equipment to improve highly-efficient recovery level in terms of optimizing the layout, simplifying mining system and improving production efficiency.

(4) China should grasp the opportunity of the reform, promote the coal industry integration and increase the industry concentration. Combing with the current reform of supply-side and state-owned enterprises, China should shut down the illegal and backward coal mines in East and Southern China and other regions and reduce the numbers. The integration of coal mining enterprises should be encouraged. And large-scale deposited resources should be allocated firstly to large groups with leading technology and abundant capital to give full play to the leading role of resources allocation. China should focus on the construction of national energy base in Shanxi, Shaanxi, Inner Mongolia and Ningxia provinces, support the recombination between enterprises from the industries of coal, power, coal to chemical and transportation in accordance with market principles, and form several large energy groups of hundred million tons’ capacity linked to assets to carry out merger and acquisition. All this will further improve the industry concentration and the production efficiency, increase market controlling and competition ability, and thus to lead the healthy development of the coal industry.

(5) China should strengthen coal resources’ protection, and promote the sustainable development of energy. Mines with extremely complicated occurrence conditions and quality, poor security degree and economic benefits and serious damage to the environment should be restricted, especially the small coal mines, which should be taken to prohibit production in due time. As to the resources under rivers, railways and buildings in the Eastern China, extremely thick coal seam in Xinjiang province and particularly scarce coal resources, measures of temporary mining prohibition or protective mining should be implemented to protect the coal resources and promote the sustainable development.
(6) China should carry out system research of precise mining and promote safe and intelligent mining. It is reported (Yuan 2017) that by means of technologies including intelligence, intelligent control, the Internet of Things, cloud computing and big data, precise coal mining is referred as a new future mining mode integrating intelligent mining technique with few workers (unmanned), and disaster prevention and control. This mode is based on transparent spaces and geophysics, as well as multi-field coupling to achieve spatial-temporal accuracy and efficiency. It is able to comprehensively consider factors relating to mining under different geological conditions, including mining influences, relevant factors inducing disasters, and ecological destruction caused by exploitation. To carry out the scientific system research of precise coal mining and promote the safe and intelligent mining, scientific problems such as digital quantitation of multi-field dynamic information (such as stress, strain, displacement, crack and seepage) during coal mining, multi-source information processing (acquisition, sensing, transmission) on working face or disturbed zones by mining activities, evaluation and screening mechanism of multi-source dynamic information based on big data cloud technology, disaster formation theory of multi-phase and multi-field coupling based on big data, intelligent simulation and control of disaster precursory information with profound perception, risk warning and key emergency rescue equipment and technology of mine disasters, should be researched and solved with priority.

4 Conclusions

(1) As the principal energy in China, coal has provided a reliable supply of energy for the national economic and social development, but after the “golden decade” of rapid development, the coal industry now is facing overcapacity, low industrial concentration and production efficiency, high pressure of safety and environment and other prominent issues. It is of great strategic significance to promote the adjustment and upgrading of the coal industry structure by studying the strategic measures of highly-efficient recovery of coal resources in China.

(2) Based on defining the connotation of highly-efficient recovery of coal resources, this paper put forward the relevant 8 indicators to reflect the highly-efficient recovery level of coal resources, summarized the present situation and main problems of China's coal recovery and made a compared analysis of the gap of coal recovery level between China and the United States and Australia.

(3) Through analyzing the development environment of China's coal industry under the new situation, this paper put forward six strategic measures to promote the highly-efficient recovery level of coal resources in China, which include giving full play to the advantages of green resources and optimizing coal mines’ development layout based on coal imports; enhancing overcapacity reduction, achieving balance between supply and demand and improving the highly-efficient recovery level; expanding the advanced experience and adopting the advanced technology and equipment to promote highly-efficient recovery; grasping the opportunity of the reform, promoting the integration of coal industry and increasing the industry concentration; strengthening coal resources’ protection, and promoting the sustainable development of energy; carrying out the system research of precise mining and promoting the safe and intelligent mining.

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