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Study on Coal Mining and Utilization Model and Elastic Development in Post-Industry Age

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Abstract: Clean, efficient, green energy utilization demand put forward new requirements for the traditional mining. Based on the theory of elastic development, taking coal resources development and utilization as the leading factor, the paper explores the coal resources production mode, coal mining enterprise management and coal mining area elastic development in the background of post-industry age from the perspective of technological development, realistic requirements and field cooperation. Conclusion: (1) Changes in production methods, in the post-industrial age, the coal exploitation and utilization will achieve green precision mining for less consumption and less ecological disturbance, circular economy for clean and efficient utilization, zero emissions and harmless disposal of waste; (2) Management innovation of coal mining enterprise, the coal mining enterprises will realize the mine system intelligent management for the new technologies emergence of artificial intelligence, virtual simulation, internet sensing and all-round, visual real-time dynamic monitoring et al; (3) Elastic development of coal mining area, the coal mining area will realize the all-round development of engineering elasticity, economic elasticity, social elasticity and ecological elasticity for the more completed structure and functions, the more improved ability of self recovery and resist external risks, and more enhanced integrity and completeness of system.

Keywords: Coal Resources, Post-Industry Age, Green Mining, Utilization Model, Elastic Development

1. Introduction

In 1970s, Harvard sociologist Bell pointed that people had come into the post-industrial age [1]. In post-industrial age, the concepts of green, environmental protection, clean production, sustainable and other emerging development ideas make the traditional industry coal mining facing serious challenges, but as the basic energy of economic development, coal resources will still occupy an important position for a long time in future. According to the 2017 "BP World Energy Statistics Yearbook" [2], the data show that: compared to 2015, 2016 global coal consumption fell by 1.7%, but which still accounted for 28.1% of primary energy consumption. And by 2030, global coal consumption will still maintain an average annual growth of 0.5% [3].

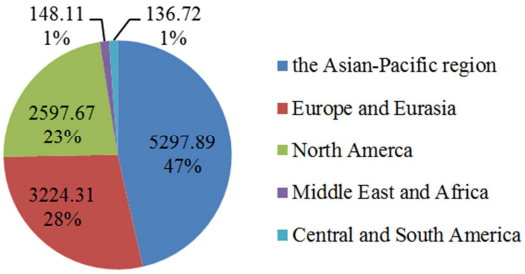
As an important basic energy, on the one hand, the large-scale exploitation and utilization of coal resources promotes the economic development, at the same time, bring out series ecological environment, health and safety issues, such as: coal mining causes the destruction of key ecological factors (such as water, soil and gas), species abundance, landscape fragmentation and so on. On the other hand, because of the limited reserves of coal resources, the over exploitation and low efficiency utilization will make coal resources waste seriously. Therefore, how to develop and utilize new technology, to realize green mining, clean production and efficient utilization of coal resources has become one of the urgent problems to be solved in the coal industry. Based on the elasticity development theory, the paper analyzes the future demand of coal resources, the new ways of coal mining, the development planning and management of coal mining area in post-industrial age, in order to provide scientific reference for realizing the efficient utilization of coal resources and the elastic development of coal mining area.

2. A Survey of Mining

After the Second World War, the rapid development of science and technology makes the social economy has undergone enormous changes, based on the perspective of the technology changing, the western scholar Bell divided society into "former industrial society", "industrial society" and "post-industrial society", and he proposed that in the late 1960s and early 1970s, Western developed countries moved from the "industrial society" to "post-industrial society" [4], human being gradually went into the post-industrial age.

2.1. Reserves and Consumption

According to the British BP Amoco (BP) global energy survey, the global coal resources have proven reserves of 113.931 billion tons in 2016, which can meet the world's 153 years demand. The global distribution of coal resources is unbalanced. Among them, the Asia-Pacific region, Europe and Eurasia and North America are the main distribution areas of coal resources, accounting for 98% of the total reserves of coal resources. The distribution of coal resources in the Middle East, Africa and Central and South America is less, accounting for 2% of the total reserves of coal resources. The proven reserves of coal resources in each region is shown in figure 1.



Figue 1. *Distribution of proven reserves of coal resources in various regions of the world in 2016.*

After 1970s, global coal consumption showed a significant upward trend, and the proportion of global primary energy consumption showed a small downward trend. The output and consumption of coal resources in the world are shown in table 1.

Table 1. *Global coal consumption and growth ratio from 1970 to 2015.*

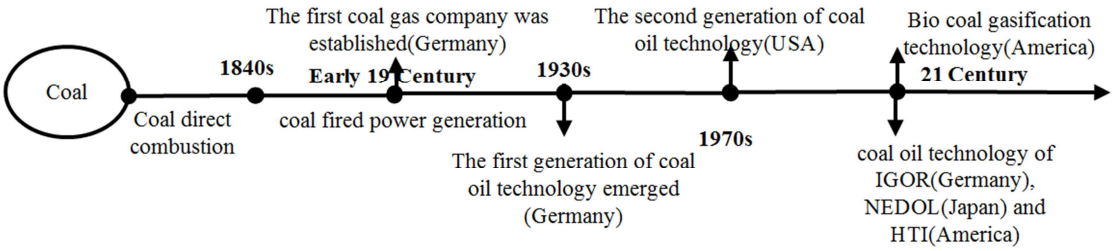
year	coal consumption/Mtoe	growth ratio	Proportion of primary energy consumption
1970	1635.0	6.65%	--
1975	1709.0	4.53%	29.59%
1980	2021.0	18.26%	30.41%
1985	2100.0	3.91%	29.36%
1990	2244.0	6.86%	27.72%
1995	2255.3	0.50%	26.50%
2000	2148.1	-4.75%	23.19%
2005	3122.4	45.36%	28.59%
2010	3635.6	16.44%	29.87%
2015	3784.7	4.10%	28.88%

2.2. Coal Mining and Utilization Before Post- Industrial Age

Coal mining methods include open pit mining and well mining.

Open pit mining is a concrete process of extracting useful minerals from a mining field that exposes the surface. Open pit mining, including exploration, topsoil stripping, perforation, blasting, mining, transportation, drainage and other processes, according to the continuity of coal mining operations, which can be divided into continuous, semi-continuous and intermittent mining. The open pit mining is suitable for the shallow coal seam, which has the advantages of high coal recovery rate, high production scale, high safety level, high degree of mechanization and low production cost [5]. Well mining refers to the use of wellbore and underground roadway system for coal mining process.

Coal-fired power generation and metallurgy are the two main ways to utilize the coal resources in the traditional utilization. With the development of science and technology, coal utilization tends to diversify. Coal oil, coal gas are the new directions of coal resources utilization. Coal utilization road over time is shown in figure 2.



Figur 2. *Coal oil, coal gas development road over time.*

2.3. Emergence of Economic, Production and Ecological Problems

In the early stage of the post-industrial age, the mining technology of coal resources was relatively simple, mainly for the power generation and metallurgical industry. Developing mining technology, improving coal production had become the main goals of the coal enterprises. For example, The United States, as one of the most advanced coal mining technology country in the world, open pit mining of the United States uses no transport method by Ramming Pile, mining machinery and equipment construction of large efficient operation, the construction of large coal mines, coal resources centralized mining underground mining. The tunnel, inclined to open up by mining one use, bolting, room and pillar mining method [6].

With the emergence of various synthetic materials and emerging energy, the traditional coal mining area is being affected gradually and facing serious economic transformation problems. For example, The German Ruhr area, where has abundant coal resources, is one of the most important industrial areas in Europe. In mid twentieth Century, due to the change of energy consumption structure and alternative energy, the coal industry has been affected, while coal mining efficiency led to coal production and coal mining efficiency reduction. At the same time, the demand for coal mining jobs decreased and the local residents were unemployed seriously. At the same time, the large-scale development and utilization of coal resources has caused serious damage to the ecological environment. The declining of leading industry, the destruction of the ecological environment, and the reduction in the number of jobs led to the Ruhr area lost its former glory.

3. Coal Mining and Utilization in Post-Industry Age

The concepts of cleaner production, green environmental protection and sustainable development, the adjustment of the global energy structure, and a series of ecological environment problems caused by the coal mining process make the coal mining enterprises face the great challenges. Developing coal mining technology, improving production efficiency, reducing environment disturbance, protection people's life and property in mining area are the only way to achieve green mining, and also the strict requirement for the sustainable development of the coal industry

3.1. New Concepts of Coal Mining

The Coal mine safety, ecological environment and economic problems in mining area became more and more serious for the expanding mining scale and growing mining speed in the industrial age. Therefore, Human must abandon the extensive mode relying on output and extensive scale of coal mining. Based on this, green mining, scientific mining, cleaner production and other new ideas on the coal resources mining began to emerge.

(1) Green mining

The degeneration of the surface vegetation, destruction of key ecological elements such as water, soil, gas and so on caused by the traditional coal mining. Therefore, based on the view of ecological protection and circular economy, Qian Minggao proposed the green mining theory.

The connotation of "green mining" refers to the mining technology which is consistent with the environment and implements "low mining, high utilization and low emission" by following the principle of green industry in the circular economy [7].

(2) Scientific mining

For the reason of restriction of mining conditions, technical level, market management system, et al, the coal mining direction needs to change from output to quality, single production to comprehensive utilization, resources and environment constraints to ecological environment friendly. Therefore, the concept of mining science was put out [8]. The connotation of scientific mining is: maximize access to natural resources under the guidance of the scientific concept of development. To achieve safe, efficient, green, economic, social sustainable development coordination by overcoming security risks brought by complex geological conditions and engineering environment.

(3) Cleaner production

The concept of cleaner production is mainly derived from a new management and defense strategy for industrial pollution control. In May 1989, the United Nations Environment Plan Industrial and Environmental Planning Center (UNEPIE/PAC) defines cleaner production as "the continued application of an integrated preventive environmental strategy applied to processes, products and services to increase overall efficiency and reduce risks to humans and the environment" [9]. The concept of cleaner production was then applied to the production and utilization of coal resources. Coal clean production is taking "prevention" measures in coal mining, processing and utilization, emissions and other aspects of the entire production cycle. Through combined the production technology, production process, management and products et al with elements of Material flow, energy, information et al, then to achieve the smallest environmental impact, the least resource use, and the best economic growth of coal production by optimizing the mode of operation [10].

In addition to the above coal mining concepts, digital wisdom mine construction [11], green mine construction [12] and other concepts have been proposed, which provided the new idea, new requirements for the scientific and rational coal resources utilization.

3.2. New Technologies of Coal Utilization

3.2.1. Recycling Mining

The large demand of coal resources makes the efficiency of coal mining gradually improved. Then, various efficient and continuous coal mining methods have been put forward. If the coal seam has the characteristics of "near level, shallow depth and large thickness", it can select the open-ground combined mining technology to improve the recovery rate of coal resources and increase produced quantity [13]. If the depth of coal seam is shallow and the thickness is moderate, the short-wall continuous mining technology can be adopted, which can improve the mining rate and increase the production of coal resources [14].

3.2.2. Consider the Extraction of Equipment Technology

Coal resources occurrence conditions, geological structure, mining depth, mining technology and equipment are the important factors which lead to the serious waste of coal resources. Precise mining refers to the overall consideration of the different geological conditions of mining disturbance, disaster factors, destruction of the ecological environment and other factors caused by coal mining, to achieve a new mining model with accurate and efficient unmanned, intelligent

mining, disaster prevention and control in time and space [15].

In the future, the coal resources will achieve precision mining, which will break the limits of the field, from the perspective of underground coal resource detection, intelligent perception and information transmission, mining disturbance and prevention, large data cloud support precision mining, multi-field coupling disaster warning alarm and no one of the intelligent mining six aspects of the comprehensive development of coal resources to achieve the precise mining [16].

3.2.3. Mining Based on Ecological Perspective

After the Green mining theory being proposed, according to the post mining strata in the: "joint" field distribution and movement law; influence regularity of rock strata movement in mining; water and gas seepage in fractured rock through law and rock stress field distribution and strata control technology, the green mining technology was put forward [17]. Green mining technology system mainly includes water preserved mining technology, simultaneous exploitation technology of coal and gas, control coal mining subsidence technology, coal underground gasification technology and gangue reduction emission technology. The application of green mining theory and technology system in coal mining, improves the efficiency of cleaner production, reduces the destruction of ecological environment in mining area, and saves the cost of environment. Green mining technology system is shown in figure 3.

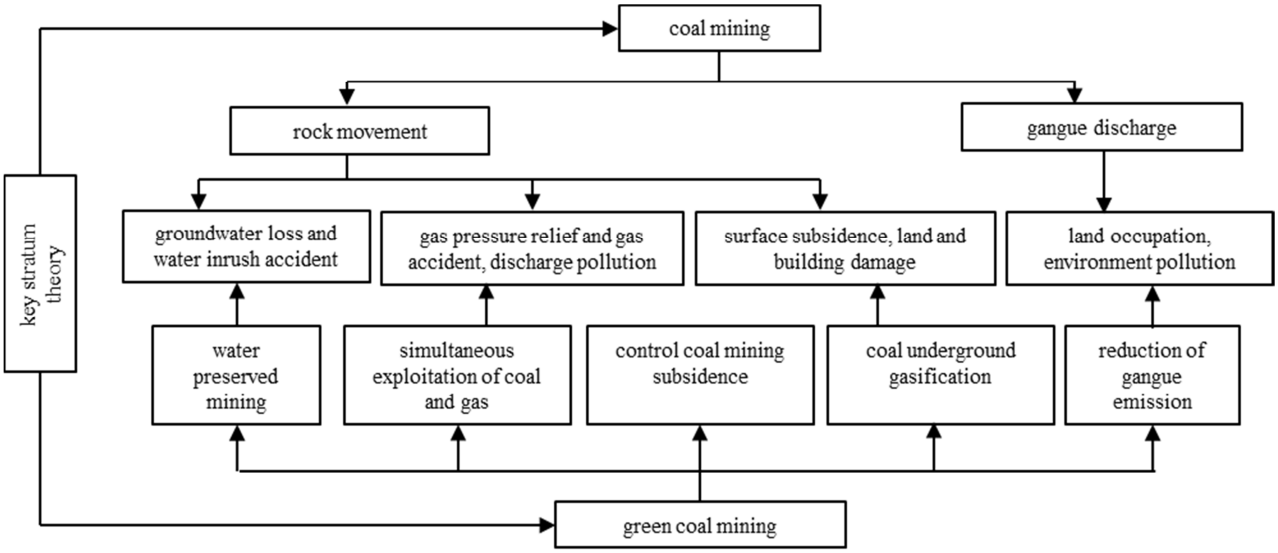


Figure 3. *Green mining technology system of coal resources.*

3.3. Wisdom Management of Mine System

Wide wisdom management of mine system is an intelligent system which taking the aim at wisdom mine construction, keeping digital mine construction as the central task, completing the precise, real-time collection, network transmission, visualization, standardization, integration, automation and intelligent service of all the information needed for enterprise management [18]. The system includes coal mine production, safety monitoring, personnel management, coal processing and utilization et al [19].

The technology of wisdom mine construction includes spatial information technology, data mining technology, cloud integration technology, intelligent mining and service technology, security guarantee system, 3D simulation, virtual reality technology and mine technical specifications and standards. Through mapping, remote sensing, internet of things sensing, accident simulation and other technical integration, to achieve a comprehensive, visual, real-time, dynamic and intelligent management of mine system [20]. Specific techniques are shown in table 2.

Table 2. *Technical composition of wisdom mine construction.*

Technical composition of wisdom mine construction	Spatial information technology	Surveying and mapping, remote sensing, geographic information system, 3S Technology
	Data mining technology	Image processing, pattern recognition, parallel rules, temporal and spatial sequence analysis
	Cloud integration technology	Cloud computing, Internet of things, infrared sensors, radio frequency identification
	Intelligent mining and service technology	Automatic scheduling, unmanned mining, intelligent communication
	Security guarantee system	Accident prediction, disaster warning, accident simulation and safety inspection
	3D simulation and virtual reality technology	Virtual simulation, 3D simulation, artificial intelligence
	Mine technical specifications and standards	Unified safety standards, data acquisition, data calibration, data fusion

4. Coal Mine Elastic Development

4.1. Coal Mine Elastic Development

Making the reasonable coal mining program, combined with scientific coal mine planning and management, is the important aspect to achieve the accurate and efficient coal mining. Limited coal resources reserves, long-term unreasonable exploitation, environmental damage and waste of resources, changes in energy consumption structure and the emergence of emerging materials et al, which have become the important problems in the coal mines development. The basic meaning of the concept of elastic development is to improve the ability of coal mine system to resolve the external shocks, maintain its primary function during a crisis [21].

With the enhancement of technological progress and management planning means, the output efficiency and utilization rate of coal mining will be improved, at the same time, the waste of coal resources will be effectively avoided. In the process of coal mining and utilization, the ecological environment destruction, natural disasters and the life safety issues of residents in the mining area can be effectively avoided, and the elastic control, elastic utilization, elastic exploitation of coal resources will be realized. To improve the elastic development of the coal mine, it is necessary to improve the self-recovery ability of the coal mine system, and maintain its structural and functional integrity, improve the production capacity, to prevent and deal with the coal mine accident response capacity; in the energy consumption structure changes, to cope with external changes, to maintain the development of vitality; and human interference, the coal mine can still maintain their own system of normal operation, to cope with external changes, from four aspects of ecological elasticity, engineering elasticity, economic elasticity and social elasticity.

4.2. Looking Forward to Future Trends in Energy Extraction

Coal resources is mostly being dominated in land, therefore, coal mining ways are divided into two aspects of well and open pit mining. However, due to the limited amount of coal resources, the continuous progress of mining technology in various fields makes the ocean, interstellar (wide rang) coal mining and harmless coal mining model possible.

In 2015, the National Aeronautics and Space Administration (NASA) proposed the Asteroid Provided In-Situ Supplies Plan (Apis). The project, based on optical mining, uses robots to obtain water from rocks space and then extract minerals from the planet's surface by collecting heat from the sun. Interstellar mining can greatly save water resources, avoid the waste of water resources and mine disasters, which will be a new choice for future coal mining.

5. Conclusion

Through the study of the new concepts, mining ways and future development direction about coal resources in post-industrial age, the result shows that: in post-industrial age, under the guidance of new concepts such as green mining, scientific exploitation and cleaner production, with the support of continuous upgrading innovative mining technology, such as open-ground combined mining, green mining technology system, artificial intelligent mining technology and so on, coal resources will achieve the accurate, efficient, continuous, pollution and no waste exploitation.

With the proposal of digital mine and intelligent mine construction, under the support of multi-technology fusion development such as virtual simulation, cloud fusion technology, internet of things sensing technology, 3S technology and artificial intelligence technology, mine ecosystem will be carried out to all-round, visualized, real-time and dynamic monitoring for standardize personnel operations, guaranteed personal safety, early warning of coal mine disasters, simulated accident, orderly communication scheduling in mining area et al. Finally, the whole mining area system will realize the intelligent management.

Based on the concept of elastic development, in the future, the coal resources will be expected to achieve elastic control, elastic exploitation and elastic utilization. The utilization efficiency of coal resources and the ability to react the structural change of the external energy consumption have been improved; The incidence of environmental disturbance caused by coal mining is obviously reduced; To be a complete system, the structure and function of coal mine system will be more and more complete and comprehensive, self-recovery and response to external changes will be significantly enhanced, the environmental problems and disaster accidents are going to be significantly reduced. Finally coal mine will achieve its ecological resilience, engineering resilience, economic resilience and social resilience.

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