

Application Prospect of Polyaluminium Chloride in Pipeline Coal Transportation Engineering

Minghang Zhang*

CCTEG Wuhan Engineering Company, Wuhan, Hubei, 430064, China

**Corresponding author*

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Abstract: Due to the characteristics of current China's energy structure, coal has been used as the main energy for a long time, but the traditional railway and highway transportation methods cannot meet the energy demand of the society. Under this background, China has introduced a new mode of coal transportation-pipeline coal transportation, and the development of new high-efficiency and environment-friendly pipeline coal transportation process has become the direction for scholars and engineers in the industry to make joint efforts. In this paper, the preparation and application of polyaluminium chloride, a common inorganic polymer water treatment agent, is combined with the process technology of Shenwei pipeline coal transportation project, and a set of innovative process flow is put forward, indicating that the polyaluminium chloride can be recycled in the whole process flow chain of pipeline coal transportation project. It is of great significance to solve the common problem of coal-based solid waste accumulation in coal industry and to develop a new and sustainable type of pipeline coal transportation project.

1. Introduction

As one of the most commonly used inorganic polymer flocculants at present, polyaluminium chloride (PAC) has the advantages of fast flocculation and sedimentation rate, high turbidity removal, less sludge, wide applicable pH range and no corrosive to pipeline equipment [1,2], and is widely used in the water treatment field of municipal, electric power, metallurgy and other industries. The industrial production of PAC has been continuously studied in China since 1970s, and its preparation technology of PAC has been quite perfect. PAC has become the water treatment agent with the most mature process, the most extensive application range and the largest sales volume in the market.

China's energy is characterized by "rich coal, poor oil, less gas", which makes coal as the main energy source for a long time as well. China's coal transportation system is dominated by railways and supplemented by highways and waterways [3]. The coal transportation volume by railways accounts for more than half of the total coal transportation volume. However, the railway coal transportation is affected by various factors such as economy and transportation efficiency, and cannot meet the gradually increasing market demand. Under such background, a new coal transportation mode-pipeline coal transportation has been introduced from foreign coal slurry transportation projects,

which has many advantages such as economy, environmental protection and strong adaptability to terrain [4]. It has very important significance to promote the development of coal transportation in China.

The pipeline coal transport is to crush and process the mined coal at the head end, then mix it with water in a certain proportion to make qualified coal slurry through pipeline transportation, which is then transported to the terminal through pumping equipment and pipelines for concentration and dehydration to prepare solid coal, or prepare high-concentration gasified coal-water slurry to supply downstream power plants and coal chemical plants. The development of pipeline coal transport technology in China began in the 1980s. In 1985, the state established the first pipeline coal transport experimental center in China in the Institute of Coal Chemistry Chinese Academy of Science to study the theory and corresponding experiments of the pipeline coal transport technology. In 1996, the State Council approved the project of “Meng (County)-Wei (Weifang)-Qing (Qingdao) Coal Pipeline Transportation Project”, with a total length of 713 km, designed to transport 7 million tons of cleaned coal annually, and a total investment of 4.8 billion yuan. However, the project was terminated in the later stage due to various factors such as financing and politics [5]. In 2001, Datong Huihai carried out pipeline transportation experiment in Tangshan Branch of the Institute of Coal Chemistry, and verified the feasibility of large-scale and long-distance pipeline coal transportation technology from data [6]. In 2010, the construction of Shenwei Pipeline Coal Transportation Project, which is EPC contracted by CCTEG Wuhan Engineering Company, was started. The total length of the project was 727 km and the transportation capacity was 10.0 Mt/a. The whole line was opened to traffic in 2020. The large transportation volume, long transport distance and the complex terrain along the whole project fully show that our country has advanced international technology in long-distance pipeline transportation of coal slurry and even other slurry [7].

At present, the application of PAC in coal industry is mainly used as a water treatment agent in the treatment of coal washing wastewater. However, there are few studies on the combination of PAC and the whole process of pipeline coal transport engineering. From the perspective of PAC preparation and application, combining with the actual process flow of Shenwei pipeline coal transport project, this paper expounds the wide application prospect of PAC in the pipeline coal transportation engineering.

2. Application of PAC in Pipeline Coal Transportation Project

2.1. Coal Preparation and Slurrying Process at Head-end Station

The head-end station of pipeline coal transport project is generally located near the coal mine which needs to be mined. It is mainly divided into two major technological processes: coal dressing and pulping. Coal dressing, also known as coal washing, is a very important step at the head-end station. Raw coal mined from the mine contains a lot of impurities. The impurities in the raw coal are removed by coal dressing, and the finished coal of different qualities is screened out. The screened finished coal, which is also called cleaned coal, is prepared into coal particles meeting the requirement of conveying granularity by special equipment such as a crusher and a mill, and then pulp is carried out according to the slurry concentration obtained by experiments and calculation. The key technical parameters of the rheological characteristics of Shenwei Pipeline project are obtained through the fluid dynamics calculation formula and corresponding experiments.

PAC can be used as a water treatment agent for coal washing wastewater at the head-end station. The main components of coal washing wastewater are micro-pulverized coal, sand, clay, silty rock, etc. When PAC is added, there will be two processes of coagulation and flocculation, so that the tiny particle of impurities in the coal washing wastewater condense into large particles and settle down [8], the treated effluent can be reused as production water for clean coal pulping. At the same time,

PAC can also be used as an additive in the coal dressing process to improve the yield of cleaned coal. When PAC is added, its positive charge can neutralize the surface charges of coal and inorganic minerals, thus reducing the cover of inorganic minerals on the coal surface and effectively reducing the ash content of cleaned coal [9]. In addition, PAC can increase the surface difference between coal and artificial minerals, promote the separation of coal and inorganic minerals, reduce the influence of high ash fine mud entraining, and promote the separation of coal and kaolinite, montmorillonite and other minerals [10], thus reducing the ash content of cleaned coal and improving the separation effect.

The current manufacturing process of PAC is quite mature, in which coal gangue is used as raw material to prepare polyaluminium chloride [11], and coal gangue is a solid waste discharged in coal mining and coal washing process. Therefore, coal gangue generated in coal mining and coal washing process can be used at the head-end station to prepare PAC, and the coal gangue can be applied to the two process flows of coal dressing and coal washing wastewater treatment to realize resource recycling. The new process chain is shown in Figure 1.

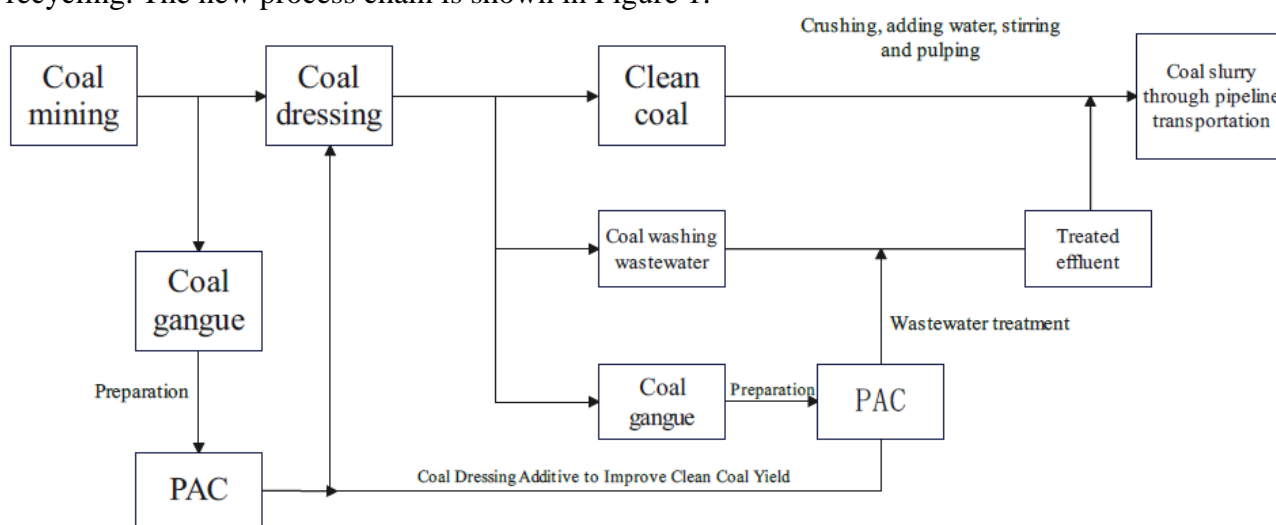


Figure 1: Application of PAC in the process flow at head-end station

Currently, a large amount of coal gangue has caused a serious pollution to the environment in China, and the impact of coal washing wastewater on the environment is more obvious [12,13]. PAC prepared with coal gangue can be used as an additive to improve the coal efficiency in the coal preparation process and water treatment agent of coal washing wastewater, the treated water can be used again in pulping technology. It can not only reduce the pollution to the environment and realize the recycling of resources, but also can improve the production efficiency. It is worth mentioning that with the development of gangue slurry pipeline transportation technology, coal gangue can be transported to PAC production workshop through pipeline from the place of production without using traditional transportation mode, which is more environment-friendly. The Xiaobaodang Goaf Surface Subsidence Treatment Project jointly contracted by CCTEG Wuhan Engineering Company and Shaanxi Tiandi Geology Co., Ltd. jointly contracted by EPC has been successfully completed in 2023 and enters the commissioning stage. The pipeline transportation part of the project is a gangue slurry conveying pipeline with a length of about 8 km.

2.2. Dehydration and Secondary Pulping Process at Terminal Station

The terminal station of pipeline coal transportation project mainly contains the dehydration process of coal slurry, and also includes the process of preparing gasified coal water slurry by using medium-concentration coal slurry through pipeline transportation. At present, coal-water slurry gasification

technology is an important direction of coal clean energy utilization in China. Many coal chemical enterprises are developing the use of coal water slurry gasification. Coal-water slurry is a solid-liquid two-phase fluid consisting of coal, water and certain additives [14]. The key factor to improve the gasification efficiency of coal-water slurry is to increase the concentration of coal-water slurry. The coal water slurry industry generally adopts a rod mill or a ball mill to prepare the coal water slurry by wet grinding. For a long time, the low slurry concentration and low gasification efficiency of the rod mill have been the technical problems in the preparation process of coal water slurry. In order to solve this problem, from the technical point of grinding equipment and grinding process, China has successively developed the graded grinding pulping process and the intermittent size grading pulping process to improve the concentration and gasification efficiency of coal water slurry by changing the particle size distribution of coal slurry. Compared with these multi-stage grinding processes, if a certain technical means can be adopted to directly concentrate the low-concentration coal-water slurry into the high-concentration coal-water slurry, the production process can be greatly simplified, the economic cost can be reduced, and PAC can realize this technical means.

At present, Pucheng terminal of Shenwei Pipeline Project adopts the slurring process after partial coal slurry dehydration and re-mixing, that is, the coal slurry dehydrated in the station is blended back into the medium-concentration coal slurry, and then the coal water slurry preparation technology is adopted for slurring. Deng Yaxiong et al. [15] took the low-concentration coal-water slurry prepared at the terminal of Shenwei Pipeline Project as a sample and added with a certain amount of PAC and ligninsulfonate. The Zeta potential of the coal slurry can be changed by virtue of the compression electric double-layer effect and the adsorption electric neutralization effect of PAC, so as to promote the destabilization and aggregation of coal slurry particles, thus improve the removal capacity of free water in the gaps of the coal slurry. Then, the concentration of the coal-water slurry can be greatly improved by using plain-grain polypropylene filter cloth and adopting the cross-flow filtration technology [15]. This method adopts direct concentration technology, which is the most simple and economical process in the preparation of gasified coal-water slurry with medium-concentration coal slurry [16].

At the terminal station of the pipeline coal transportation project, part of the dehydrated coal prepared by the process technology is transported out for sale by means of vehicles such as cars and trains, while the other part of the dehydrated coal and the high-concentration gasification coal water slurry prepared are directly provided to the nearby downstream users. These coal-electricity-chemical energy enterprises will produce a large amount of coal-based solid waste [17] mainly containing coal gangue and fly ash, which can be used as raw materials for PAC preparation. The process for preparing PAC from coal gangue has been mentioned above. Meanwhile, for the fly ash produced after power generation, the alumina contained in it can be prepared by neutralization method and alkali addition method [18], and the process technology for extracting alumina from high-alumina fly ash has also been very perfect. Therefore, PAC can be prepared by coal gangue and fly ash generated by enterprises such as coal chemical industry, power plant and other enterprises near the terminal of pipeline coal conveying project, and recycled into the concentration process flow of coal-water slurry. The new process flow chain formed is shown in Figure 2.

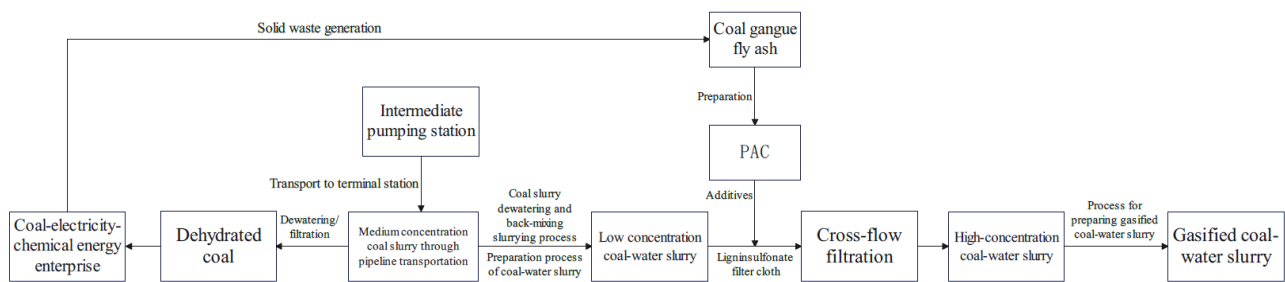


Figure 2: Application of PAC in the process flow at terminal station

3. Conclusions and Prospects

Under the current situation of China's energy structure, it is of great significance to develop the pipeline coal transportation project. Combined with the world's largest Shenwei Coal Pipeline Transportation Project that is EPC contracted by CCTEG Wuhan Engineering Company, a set of innovative technology has been put forward i.e. PAC is prepared from coal-based solid waste generated in the normal process flow chain at the head-end station and the terminal station of the pipeline coal transportation engineering. At the head-end station, PAC is applied to the process of coal preparation to conduct sewage treatment and improve the yield of cleaned coal; at the terminal station, PAC is applied to the process of concentrating the coal-water slurry and then preparing the high-concentration gasified coal-water slurry. Through the combination of pipeline coal transportation engineering practice, relevant technology and experiment with the preparation technology and application of PAC, this paper aims to expand the broad application prospect of PAC in pipeline coal transportation engineering, and at the same time to provide theoretical and technological guidance for development of resource-efficient utilization and environment-friendly pipeline coal transportation engineering.

In this new process chain, the preparation technology and application of PAC are very mature, and there are engineering practices. Other relevant coal slurry preparation and transportation technologies have also been successfully applied to Shenwei coal pipeline transportation project. At present, the concentration technology of coal-water slurry is only successful in the experimental stage. Its practice in the engineering will be the direction that we need to research and develop in the future!

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