Comparison and Summary of Relevant Standards for Comprehensive Utilization of Fly Ash at Home and Abroad

Shengxiang Jin¹, Zhihong Zhao², Shifeng Jiang³, Jian Sun², Haibin Pan², Long Jiang³*

¹ Beijing Jingneng Power Co., Ltd., Beijing, 100124, China
² Jinglong Power Plant Co., Ltd., Wulanchabu, 012199, China
³ North China Electric Power Research Institute Co Ltd., Beijing, 100045, China
*Corresponding author’s e-mail: jiang.long@ncepri.com.cn

Abstract. Based on the comprehensive utilization situation of fly ash in some countries, the contents and characteristics of the existing fly ash comprehensive utilization standard systems of these countries were discussed and compared, so as to provide guidance and suggestions for improving the standard system and the comprehensive utilization of fly ash in China. The average comprehensive utilization rate of fly ash in China is 70%, which is mainly used in building materials, but is relatively low in road, backfill and other scopes. Compared with developed countries, the scope and limit value of indexes involved in the standards of fly ash in China are loose, and the fields involved are mostly traditional building materials and infrastructure construction. The comprehensive utilization of fly ash of China can be improved from the following points: the indexes investigated in standards should reflect and conform to the particularity of China; the comprehensive utilization standard of fly ash should be more suitable for the local region; the power plants should actively explore and improve their own comprehensive utilization.

1. Introduction

The national policy of using coal as the basic fuel for electric power production will not change in a long time [1]. After burning, 1t raw coal can produce 250~300kg fly ash. At present, the pressure of environmental protection is increasing day by day, the problem of solid waste disposal is prominent, and the operation form of traditional coal-fired power enterprises in the power industry is becoming more and more serious. The solid waste disposal, especially the fly ash generated after coal combustion, is becoming more and more important and urgent in the production and operation activities of coal-fired power plants [2].

The comprehensive utilization of fly ash can reduce the output of solid waste and harm to the environment, and can produce a variety of useful products [3-4]. Large-scale production of building materials and infrastructure construction using fly ash is mature for each country [5]. However, the other application ways not only have small consumption of fly ash, but also have various restrictions on industrialization. The choice of other ways depends on the industrial structure and market demand for each country. Different application conditions also create different standard systems for comprehensive utilization of fly ash in different countries. According to their own situation, various countries have formulated various standards for fly ash to guide their comprehensive utilization of fly ash. The purpose of this paper is to discuss and compare the contents and characteristics of the existing standards.
fly ash comprehensive utilization standard system in various countries on the basis of clarifying the comprehensive utilization situation of fly ash in various countries, so as to provide guidance and suggestions for improving the standard system of fly ash in China, and finally promote the comprehensive utilization of fly ash in China.

2. Comprehensive utilization of fly ash

In 2016, the world produced of fly ash was about 1.143 billion tons, with an average utilization rate of 60%. Among them: China was about 600 million tons, with a utilization rate of 68-70% (comprehensive utilization of 408 million tons); the United States was about 44 million tons, with a utilization rate of 54% (comprehensive utilization of 23.76 million tons); Japan was 12 million tons, with a utilization rate of nearly 100%; the European Union was 40 million tons (all the coal-fired solid wastes in the 15 countries of the European Union), and the utilization rate was 90% (comprehensive utilization of 36 million tons); India was 169 million tons, with a utilization rate of 63% (comprehensive utilization of 106 million tons) [6].

Main utilization ways of fly ash in various countries was shown in Figure 1. The comprehensive utilization of fly ash in various countries depends on the output of fly ash, the development of technology, environmental protection requirements, the scarcity of raw materials, industrial structure and other factors. In general, the most widely application of fly ash is building materials for various countries, and the application selection of other ways is affected by the policies and industries of each country. Japan has a relatively more applications in the aspect of high value-added utilization, due to the limitation of raw materials in Japan. Fly ash plays a more important role in replacing raw materials in Japan.
3. Comparison of fly ash standard system

3.1. Present situation of fly ash standard system in China

Standard system of fly ash in China was shown in Figure 2. At present, there are 55 kinds of relevant standards for fly ash in China, including: 10 kinds of national standards, 23 kinds of industrial standards and 22 kinds of local standards. Among them, half of them are in the field of building materials, and the existing standards lack in the areas of high added value, classification, specification, agriculture and environmental protection.

3.2. Comparison of fly ash standard system

Taking the quality of fly ash in concrete as an example, the main national standards of fly ash for concrete were listed in Table 1 [7-8]. Because of the characteristics of fly ash and the domestic situation, different countries have different emphasis on the selected factors. For example, Europe has more strict environmental indicators monitoring, so it has added more composition indicators of fly
ash; because Japan is located in the seismic zone, it pays more attention on the strength parameters of fly ash [9]. Generally speaking, the indexes and limit value of the standards for fly ash in China are loose compared with those of developed countries. Among them, Japan and EU were the strictest, and China is at the same level with the United States.

The classification standards of fly ash in different countries are different. China and the United States are mainly based on the content of CaO, Japan is based on performance, and EU is based on fineness and loss on ignition. The difference of classification standard and different kinds of standard value determines the final application way. In comparison, the index difference of different types of fly ash between China and Japan is more obvious.

Table 1. Standards of fly ash for concrete in various countries.

| Items                      | China | USA | Japan | EU    |
|----------------------------|-------|-----|-------|-------|
| Physical parameter         |       |     |       |       |
| fitness (0.045mm weight of screen residue) % | ≤12.0 | ≤34.0 | ≤10   | ≤13   |
| density (g/cm³)            | ≤2.6  |     | ≥1.95 | ≤0.225|
| BET cm²/g                  | <95   | <95 | ≥5000 | /     |
| water demand ratio %       | <95   | <95 | ≥97   | /     |
| Chemical composition       |       |     |       |       |
| loss on ignition %         | ≤3.0  | ≤6.0 | ≤3.0  | ≤7    |
| Water %                    | ≤1.0  | ≤3  | ≤1.0  |       |
| SO₃ %                      | ≤3.0  | ≤4.0 | /     | ≤3.5  |
| free CaO %                 | ≤1.0  |     | /     | ≤1.6  |
| active CaO %               |       |     |       |       |
| SiO₂+Al₂O₃+Fe₂O₃ %         | ≥50.0 | ≥50.0 | ≥45.0 | ≥25.0 |
| SiO₂ %                     |       | /   | ≥5.0  | /     |
| Chloride %                 |       | /   | ≥10   | /     |
| alkali salt %              |       | /   |       | ≤5.5  |
| Phosphate %                |       | /   |       | ≤5.5  |
| Strength activity          |       |     |       |       |
| strength activity index % (7d) | /   | ≥75.0 | /     |       |
| strength activity index % (28d) | ≥70.0 | ≥75.0 | ≥90.0 | ≥70   |
| strength activity index % (91d) | /   | /   | ≥100.0 | ≥80   |

3.3. Existing problems and advices

(1) The standard system of fly ash comprehensive utilization in China is not perfect, and the indexes investigated in the standard should reflect and conform to the particularity of China. For example, the control concentration of NOx in China is lower than that in developed countries, which is easy to cause excessive ammonia injection. Ammonia in flue gas is mainly concentrated in fly ash, which will affect the quality of fly ash and release ammonia. The denitrification fly ash, which is widely used in modern engineering construction in China and other developed countries, has not specified the ammonia limitation and test method, but the ammonia escape situation in China is more serious. The application of fly ash in concrete can increase the index of Cl⁻, especially the products that will participate in the reinforcement, so as to avoid corrosion.

(2) The comprehensive utilization standard of fly ash should be more suitable for the local region because of the comprehensive utilization rate of fly ash in different regions are different. Each region should explore the most suitable standards for the comprehensive utilization of fly ash in this region, so as to guide the comprehensive utilization of fly ash. For the northwest region, the traditional application of building materials is gradually narrowing, so it is necessary to quickly formulate relevant guidance standards to guide the comprehensive utilization of fly ash in backfill, soil improvement and other aspects.

(3) Existing standard system of China only involves traditional utilization ways such as building materials and infrastructure construction. However, there are no corresponding standards in other aspects of application, such as environmental protection, backfill, catalyst, functional materials, agriculture and so on, which limits the promotion and standardized application of other applications in China, and the ash production units cannot carry out corresponding utilization methods without standards. Therefore, the power plants should actively explore and improve their own comprehensive
utilization of fly ash, and form corresponding application standards after the technology is mature, so as to promote the comprehensive utilization of fly ash in China.

4. Conclusions
The average comprehensive utilization rate of fly ash in China is 70%, which is mainly used in building materials. Compared with other developed countries, the application rate of fly ash in road and backfill is relatively low. The comprehensive utilization of fly ash is far below the national level due to the large output of fly ash and the demand decrease of building materials industry in Western China. Compared with foreign developed countries, the scope and limit value of indexes involved in the standards of fly ash in China are loose, and the fields involved are mostly traditional building materials and infrastructure construction, which cannot guide the application of fly ash in other fields effectively.

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