Production of Prebaked Anodes Using Coal-Based Co-Coking Coke

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Abstract

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To address the shortage of petroleum coke resources suitable for prebaked anode production, the high energy consumption and cost associated with the high-temperature calcination required for low-ash coal to make prebaked anodes, and the difficulty of directly using low-ash coal produced by coal deashing (which is often powdery), a method was developed by blending different proportions of low-ash coal and vacuum residue for co-coking. The resulting co-coking mixed coke was then calcined at various temperatures, and the calcined mixed coke was used to produce prebaked anodes. Research results indicate that co-coking coke containing 24 % coal, calcined at 1300 °C, produces a calcined mixed coke suitable for the production of prebaked anodes, and the physico-chemical properties of the produced coal-added prebaked anodes meet industry standards.

Keywords: Prebaked anodes, Low-ash coal, Co-coking coke.

1. Background

In China, almost 100 % of the carbonaceous aggregate for aluminium electrolysis carbon anodes is petroleum coke, accounting for over 60 % of the petroleum coke consumption in the country. Due to the rapid development of the aluminium industry and the significant increase in coke demand from the new energy industry, there is a shortage of high-quality petroleum coke for the production of prebaked anodes in aluminium electrolysis. It is imperative to find alternative carbon materials to replace petroleum coke, thereby diversifying the anode coke sources. Several domestic and international research institutions have carried out experimental studies on preparing prebaked anodes by adding low-ash coal. Yingtao Luo et al. [1] used low-ash anthracite from Ningxia as raw material, calcined at temperatures of 1800–2200 °C, and replaced 20 % of petroleum coke with calcined anthracite to produce carbon anodes that met the quality requirements of the industry standard YS/T 285 for TY-2 carbon anodes. Fachuang Li et al. [2] analysed the performance of anodes prepared from different mixtures of coking coal, varying the proportion of coal added. Patent CN101255572B [3] uses calcined anthracite and calcined petroleum coke as aggregates, mixed with binders, to make aluminium carbon anodes. Patent CN101698947B [4] uses flotation deashed coal and pulverized raw petroleum coke as raw materials to prepare aluminium electrolysis carbon anodes. The preparation process involves blending the flotation deashed coal with pulverized raw petroleum coke, compressing it into lumps, drying, and calcining to produce composite calcined coke, which replaces part or all of the petroleum coke in aluminium carbon anode production. However, these studies require low-ash coal to be calcined at temperatures above 1800 °C to meet the requirements for prebaked anode coke, resulting in high energy consumption and cost. Additionally, during the deashing process, these coals are typically pulverized into very fine particles, making direct calcination difficult. They must be pressed into blocks with added binders before calcination, further increasing production costs. This experiment mixed powdered low-ash coal with vacuum residue, then co-coked them. The resulting co-coking coke can be calcined at lower temperatures to produce calcined coke suitable for use in carbon anodes. This provides an economically efficient technical solution for replacing petroleum coke in the production of carbon anodes for aluminium electrolysis.

2. Co-coking Experiment of Low-Ash Coal and Vacuum Residue

2.1 Experimental Setup and Materials

The experiment was conducted in a temperature-controlled muffle furnace. The low-ash coal was sampled from the National Institute of Clean-and-Low-Carbon Energy, using bituminous coal from the Hongshaquan Coal Mine in Xinjiang, which underwent deashing through the sub-molten salt method to produce low-ash coal. Its physicochemical properties are shown as below.

Table 1. Physicochemical properties of low-ash coal.

Physicochemical Indices	Unit	Analysis Results
Ash Content	%	0.12
Sulphur Content	%	0.08
V	%	< 0.0005
Na	%	0.029
Ca	%	0.044
Si	%	0.0061
Fe	%	0.0071
Ni	%	0.0007
Ti	%	0.0047

Table 2. Size distribution of low-ash coal.

Particle Size	> 1 mm	1–0.5 mm	0.5–0.3 mm	0.3–0.15 mm	0.15–0.075 mm	< 0.075 mm
Weight Percent (wt%)	2.4	17.2	16.5	12.7	19.7	31.5

The vacuum residue was sourced from Chambroad Petrochemicals, and its physicochemical properties are as follows:

Table 3. Physicochemical properties of vacuum residue.

Physicochemical	Unit	Analysis Results	Notes
Carbon Residue	%	15.72	Weight Percent
Ash Content	%	0.07	Weight Percent
Salt Content	mg/L	48.98	
S	%	2.46	
Na	μg/g	12.00	
Mg	μg/g	9.63	
Al	μg/g	6.53	
Si	μg/g	14.31	
P	μg/g	1.19	
Ca	μg/g	40.69	
V	μg/g	173.54	
Fe	μg/g	54.48	
Ni	μg/g	57.34	
Asphaltenes	%	5.30	Weight Percent
Saturates	%	24.29	Weight Percent
Resins	%	24.94	Weight Percent
Aromatics	%	38.17	Weight Percent

Table 6. Conventional physicochemical properties of coal-added anodes.

Sample ID	Bulk Density /g.cm^{-3}	Electrical Resistivity /μΩm	Ash Content /%	True Density /g.cm^{-3}	Compressive Strength /MPa
1	1.477	59.1	0.51	2.04	38
2	1.482	58.5	0.46	2.03	
3	1.489	57.8	0.43	2.04	37
4	1.490	56.8	0.44	2.03	
Grade A Standard	1.56	57	0.5	2.05	35
Grade B Standard	1.53	62	0.7	2.03	32

Table 7. Air reactivity and CO_2 reactivity of coal-added anodes.

Sample ID	CO_2 Reactivity			Air Reactivity		
	Gasification	Spalling	Residual	Gasification	Spalling	Residual
1	13.0	5.2	81.8			
2				18.2	9.4	72.4
3	12.6	5.3	82.1			
4				16.8	8.4	74.8
Grade A			85			
Grade B			80			

6. References

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