Deposition of Silica Aluminum Using an Alkali Solution of Fly Ash

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ABSTRACT

This study investigated the deposition process of fly ash alkali solution containing silica. The effects of deposition pH, temperature, speed, and time on silicon and aluminum deposition rates were studied. Oil value was analyzed because of the presence of aluminum silica in white carbon black. Results show that the optimum deposition conditions are as follows: pH of 7, deposition temperature of 60 °C, deposition rotation rate of 100 r/min, and deposition time of 4 h.

EXPERIMENTAL SECTION

Raw Materials and Equipment

Fly ash from a thermal power plant was used. This ash has a silicon content of about 28% and the mass fraction of aluminum is about 44%, which is mainly in the form of calcium aluminum silicate and mullite. The contents of silicon and aluminum in acid solution are 0.115 and 0.0027 g/ml, respectively.

Box-type resistance furnace (SPJX-8-13 type), glass reaction vessel, vacuum pump (2XZ-2), constant temperature drying box (DNG-9090B), and T890 automatic titration were used in the experiments.

Test Principle and Method

Fly ash was mixed with soda ash, and high temperature calcination was performed. Acid dissolution of the sample was also conducted using acid leaching solution. Acid liquid titration was carried out by dissolving the sodium hydroxide solution in the automatic titration instrument. After sediment filtration, the obtained
silica containing residue was dried. The silicon and aluminum contents in acid leaching solution and filter residue were analyzed. The silicon and aluminum contents and silica deposition rates were calculated. Determination of SiO$_2$ by silicon molybdenum blue spectrophotometry Al$_2$O$_3$ was determined by EDTA titration.

For the determination of aluminum containing amorphous silica value, the determination method for oil GB/T7044-2013 national standard for carbon black pigment was used.

**EXPERIMENTAL RESULTS AND DISCUSSION**

**Influence of pH Value on the Deposition**

Test condition: The deposition temperature is 50 °C, the deposition rotation rate is 200 r/min, and the deposition time is 4 h. Figure 1 shows the effect of the deposition pH on the silica and alumina contents and silica deposition rate of silicon. Figure 2 presents the influence of pH on the oil absorption of white carbon black. The pH was between 6 and 10, thus silica sol has the fastest floc settling down time under neutral conditions. SiO$_2$ in strong alkali medium are mainly H$_2$SiO$_4^{2−}$ and H$_3$SiO$_4^{2−}$ and are negatively charged and not gelling. Under acidic conditions, H$_4$SiO$_4$ exists, which is the most prone to gelling. In neutral pH condition, the acid easily forms a continuous 3D network structure, which is formed by the Si–O–Si bond of water loss. Hence, the most suitable pH for deposition is 7.

![Figure 1. Effect of pH on the deposition rate of silicon and silicon aluminum content.](image-url)
Effects of Deposition Temperature

Test condition: The deposition pH is 5, the deposition rotation rate is 200 r/min, and the deposition time is 4 h. Figure 3 presents the influence of deposition temperature on the deposition rate of silicon aluminum and silica silicon aluminum contents. Figure 4 shows the influence of deposition temperature on the oil absorption of white carbon black. When the temperature is not up to the nucleation temperature, no silica formation was observed, instead silica sol. However, beyond 60 °C, the particle growth was faster with the increase of temperature, and particle acceleration collision structure was closed to the nuclear periphery; moreover, white carbon black was more dispersed. Thus, the optimum deposition temperature considered is 60 °C.

Figure 3. Effect of deposition temperature on the deposition rate of aluminum and silicon content.
Influence of Deposition Rotation Rate

Test condition: The deposition pH is 5, the deposition temperature is 60 °C, and the deposition time is 4 h. Figure 5 shows the influence of deposition rotation rate on the silicon aluminum content and deposition rate. Figure 6 presents the influence of the deposition rotation rate on the oil absorption of white carbon black. Increased speed can exacerbate the mixture in the material system and accelerate the molecular movement and collision; with faster collision, firmer structure is formed, hence the optimum deposition speed considered is 100 r/min.

Figure 5. Effect of deposition rotation rate on silicon aluminum content and deposition rate.
Influence of Deposition Time

Test condition: The deposition pH is 5, the deposition temperature is 60 °C, and the deposition rotation rate is 200 r/min. Figure 7 shows the effect of deposition time on the deposition rate and content of the silicon and aluminum. Figure 8 presents the effect of deposition time on the oil absorption of white carbon black. At the deposition time of 2 h, particle agglomeration was observed; at 4 h, after complete deposition, the colloidal particles moved to the nuclear center for a continuous connection. Consequently, the particles are tightly around the nuclear periphery, and white carbon black dispersion is worse. Therefore, the optimum deposition time is considered at 4 h.
CONCLUSIONS

Results show that fly ash with alkali solution can be employed in the deposition of aluminum containing white carbon black under the following optimal conditions: pH of 7, deposition temperature of 60 °C, deposition rotation rate of 100 r/min, and deposition time of 4 h. Under the optimal conditions, the silicon and aluminum deposition rates were 97.43% and 66.45%, respectively. The silicon and aluminum contents in the aluminum silica were 93.25% and 7.97%, respectively. In addition, the oil absorption value of 1 g of fly ash was 200 mL·g⁻¹. Therefore, the fly ash alkali solution has satisfied the standards for industrial production.

REFERENCE


