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PRODUCTION AND PHYSICOCHEMICAL CHARACTERIZATION OF TU-5 GRADE CARBON BLACK FROM ACETYLENE SOOT FOR RUBBER APPLICATIONS

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Abstract: This study presents the production of TU-5 grade carbon black through the processing of carbonaceous soot generated during acetylene production and the evaluation of its physicochemical properties. The obtained carbon black sample was analyzed in the laboratories of "Birinchi Rezinotexnika Zavodi" LLC FE and the Tashkent Scientific Research Institute of Chemical Technology in accordance with ASTM, ISO, and GOST standards. The principal quality indicators of TU-5 grade carbon black, including iodine adsorption number, oil absorption number, compressed oil absorption number, heating loss, ash content, powder volume, and sieve residue, were compared with those of industrial carbon black grades N220, N234, N326, N330, N375, and N660. The results demonstrated that TU-5 grade carbon black possesses high surface activity, a well-developed aggregate structure, low ash content, and good dispersibility. These findings confirm the potential applicability of this product as a locally produced reinforcing filler capable of replacing imported carbon black in the rubber industry.

Keywords: carbon black, TU-5 grade, acetylene soot, local raw material, rubber compound, reinforcing filler, iodine adsorption number, oil absorption number, ash content, dispersibility, ASTM standard.

In rubber manufacturing technology, the incorporation of reinforcing fillers, particularly carbon black, is one of the most important factors contributing to the improvement of elastomer properties after vulcanization. Carbon black is a key reinforcing component in rubber compounds, significantly enhancing the tensile strength, tear resistance, elasticity, and resistance of vulcanizates to repeated deformation. The reinforcing efficiency of carbon black depends on its particle size, aggregate structure, specific surface area, and the degree of interfacial interaction with the elastomer matrix.

One of the principal parameters characterizing the rheological behavior of unvulcanized rubber compounds is Mooney viscosity. As both the concentration and structural complexity of carbon black increase, the Mooney viscosity of the rubber compound also increases. Elastomer layers adsorbed on the carbon black surface and strongly associated with its aggregates form the so-called "bound rubber." The amount of bound rubber increases with increasing specific surface area of carbon black. Consequently, highly dispersed carbon black grades possessing a well-developed surface tend to increase the viscosity of rubber compounds more significantly.

The internal structure of rubber compounds is formed through physicochemical interactions between carbon black and elastomer macromolecules. This structure directly influences viscosity, processing characteristics, and the final mechanical properties of the vulcanizates [1, pp. 6–9; 2, pp. 273–282].

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Carbon blacks used in the rubber industry are generally classified as high-reinforcing, semi-reinforcing, and low-reinforcing grades according to their reinforcing efficiency. The reinforcing effect primarily depends on particle size, specific surface area, and aggregate structure. High-reinforcing carbon blacks typically possess primary particle sizes ranging from 18 to 30 nm and significantly improve the tensile strength, abrasion resistance, and resistance to dynamic loading of rubber vulcanizates. This category includes N110, N115, N220, and N234 grades. Such carbon blacks are widely used in tire tread compounds, conveyor belts, and rubber products subjected to severe mechanical stresses.

Semi-reinforcing carbon blacks are characterized by relatively larger particle sizes, generally ranging from 30 to 60 nm, and a lower specific surface area [3, p. 977; 4, p. 744]. They provide good processing characteristics and ensure an optimal balance between strength and elasticity. This category includes N330, N339, N550, and N660 grades, which are commonly used in tire carcasses, sidewalls, and general-purpose rubber products.

Low-reinforcing carbon blacks possess particle sizes greater than 60 nm and are primarily used to preserve rubber elasticity and regulate hardness. These grades are incorporated into rubber products that do not require high strength but must retain good deformation properties. The industrial classification of carbon blacks is based on ASTM D1765, which establishes an internationally recognized system for identifying carbon black grades according to particle size, reinforcing activity, and structural characteristics. At present, ASTM D1765 remains one of the most widely adopted standards among carbon black manufacturers and consumers worldwide [5, p. 4; 6, pp. 41–50].

Experimental Section

To obtain carbon black, the initial carbonaceous raw material was first purified from mechanical impurities by sieving through a 60 µm sieve in accordance with ISO 3310-1. The purified material was subsequently treated in a reactor with the addition of a solvent, and polycyclic aromatic hydrocarbons (PAHs) were extracted at 70 °C.

In the second stage, sulfanol was introduced as a surfactant-based dispersing agent, and the process was conducted at 70 °C. The addition of sulfanol reduced the surface tension of the medium and promoted the formation and homogeneous distribution of finely dispersed carbon particles. This increased the accessibility of the particle surface and facilitated the transfer of metal ions into solution during the subsequent purification stage.

Chelation treatment was then carried out at pH 7.0–7.5 and 60 °C using a chelating agent. Under these conditions, metal ions located on the carbon particle surface were converted into soluble complex compounds and transferred into the liquid phase. As a result, the effective surface area of the dispersed particles increased, and the purification efficiency of the carbon phase was enhanced.

Following the chelation process, the suspension was washed twice with distilled water. The purified carbon black was then separated by filtration and dried at 130 °C. The resulting product was designated as TU-5 grade carbon black.

The purification mechanism involved the adsorption of sulfanol molecules onto the carbon black surface, dispersion of particles through steric stabilization, and subsequent complexation of surface-associated metal ions such as Fe^{2+}, Ca^{2+}, Mg^{2+}, and Zn^{2+} by the chelating agent. The hydrophobic tails of sulfanol molecules were adsorbed onto the carbon surface, whereas the hydrophilic head groups remained oriented toward the aqueous phase, thereby providing colloidal stability to the dispersed particles. During the subsequent stage, chelating agent molecules coordinated the exposed metal ions associated with the carbon surface and removed them from the carbon phase in the form of soluble complexes. Consequently, a purified carbon black product with a significantly reduced content of metallic impurities was obtained.

The TU-5 grade carbon black was produced from local raw materials, specifically through the processing of carbonaceous soot generated during acetylene production. The

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physicochemical and technological properties of the obtained product were evaluated in the laboratories of "Birinchi Rezinotexnika Zavodi" LLC FE and the Tashkent Scientific Research Institute of Chemical Technology.

All experimental analyses were conducted in accordance with applicable ASTM, ISO, and GOST standards, as well as the internal technical specifications of the enterprise. The principal quality indicators of TU-5 grade carbon black were compared with those of commercially available industrial grades, and its suitability for application in rubber-technical products was assessed.

The analytical results demonstrated that the physicochemical properties of the synthesized TU-5 grade carbon black satisfy the technical requirements established by the enterprise. Furthermore, the obtained data confirm the feasibility of utilizing this material as a locally produced reinforcing filler capable of partially or fully replacing imported carbon black in rubber-technical applications.

Table 1.

Comparison of the physicochemical properties of TU-5 grade carbon black with industrial carbon black grades and plant technical specifications

	Class	Test parameters	Quality indicators							Standard test method
			Specification values						TU-5	
			N220	N234	N326	N330	N375	N660		
		Iodine adsorption number (g/kg).	121±7	120±7	82±6	82±6	90±6	36±5	116.5	ASTM D 1510
		Oil absorption number (m^3/kg)	114±6	125±7	72±6	120±6	114±6	90±5	120.4	ASTM D 1510
		Compressed oil absorption number (m^3/kg)	98±6	102±6	68±6	88±6	96±6	74±5	81±7	ASTM D 2414
		Loss on heating at 125 °C ≤ (%)	3.0	3.0	3.0	3.0	3.0	3.0	0.33	ASTM D 3493
		Ash content ≤ (%)	0.7	0.7	0.7	0.7	0.7	0.7	0.4	ASTM D 1506
		Powder volume ≤ (%)	10	10	10	10	10	10	10	ASTM D 1508
		45 µm sieve residue ≤ (mg/kg)	1000	1000	1000	1000	1000	1000	189	ASTM D 1514

Table 4.1 presents a comparison of the physicochemical properties of TU-5 grade carbon black produced from local raw materials with those of widely used industrial carbon black grades, including N220, N234, N326, N330, N375, and N660, as well as with the technical requirements established by the enterprise.

According to the data presented in Table 4.1, the iodine adsorption number of TU-5 grade carbon black was 116.5 g/kg. This value is comparable to those of N220 and N234 grades, indicating that the TU-5 sample possesses a relatively well-developed specific surface area. A

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high iodine adsorption number is generally associated with a finely dispersed particle structure and an enhanced ability of carbon black to interact with the rubber matrix at the interfacial level.

The oil absorption number of TU-5 carbon black was determined to be 120.4 m^3/kg. This value is very close to that specified for N330 grade and slightly higher than those reported for N220 and N375 grades. These results indicate that TU-5 carbon black possesses a well-developed aggregate structure and can effectively function as a reinforcing filler in rubber compounds.

The compressed oil absorption number was measured at 81 ± 7 m^3/kg, which falls within the range typically observed for N326 and N660 grades. This finding suggests a moderate level of structural stability of the TU-5 carbon black aggregates under compression. Although the initial oil absorption capacity is relatively high, partial compaction of the aggregate structure during compression results in a reduction of the oil absorption value.

The loss on heating at 125 °C was found to be 0.33%, which is significantly lower than the maximum permissible limit of 3.0%. This result indicates a low content of moisture and volatile substances in the TU-5 sample, confirming both its thermal stability and the effectiveness of the drying process.

The ash content was determined to be 0.4%, which is below the standard limit of 0.7%. This finding confirms the low concentration of inorganic impurities in TU-5 carbon black and demonstrates the effectiveness of the purification and processing procedures applied to the raw material. A low ash content is particularly beneficial for rubber applications, as inorganic impurities may act as defect centers within the elastomer matrix and adversely affect product performance.

The powder volume of the TU-5 sample was 10%, which corresponds to the specified requirements for all of the industrial grades included in the comparison. The residue retained on a 45 μm sieve was 189 mg/kg, substantially lower than the maximum allowable value of 1000 mg/kg. This result indicates that the TU-5 carbon black was effectively purified from coarse mechanical impurities and agglomerated particles and exhibits a satisfactory degree of dispersion.

Overall, the results presented in Table 4.1 demonstrate that the principal physicochemical properties of TU-5 grade carbon black comply with both the enterprise technical specifications and the limits established by ASTM standards. In terms of iodine adsorption number, TU-5 exhibits characteristics similar to those of N220 and N234 grades, whereas its oil absorption number is comparable to those of N330 and N375 grades. Furthermore, the compressed oil absorption number indicates a moderate level of aggregate structural stability. Based on these findings, TU-5 grade carbon black may be regarded as a promising locally produced reinforcing filler suitable for application in rubber-technical products as a potential substitute for imported carbon black.

Conclusion. The iodine adsorption number of TU-5 grade carbon black was 116.5 g/kg, while the oil absorption number reached 120.4 m^3/kg. The loss on heating was 0.33%, the ash content was 0.4%, and the residue retained on a 45 μm sieve was 189 mg/kg. All of these parameters comply with the technical requirements of the enterprise and the limits specified by ASTM standards.

The obtained results indicate that TU-5 carbon black possesses high surface activity, a well-developed aggregate structure, low ash content, and good dispersibility. Based on its physicochemical characteristics, TU-5 grade carbon black exhibits properties comparable to those of industrial grades N220, N234, and N330. Therefore, it can be considered a promising locally produced reinforcing filler for application in the rubber industry and as a potential alternative to imported carbon black.

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