ROASTING OF ALUMINA-CONTAINING MATERIAL IN A ROTARY KILN.

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Annotation: *This study examines the dehydration and firing of kaolin clays in a rotary kiln to optimize aluminum oxide extraction during nitric acid leaching. Previous pilot-scale tests in a fluidized bed furnace achieved up to 87% acid-soluble aluminum oxide at 750°C, but required granulation and extensive dust collection. Large-scale experiments using a 12-meter rotary kiln with an external furnace were conducted on kaolin clay from the Angren deposit and substandard bauxite. The study investigated temperatures from 600 to 800°C and residence times of 1–2 hours. Results indicate that a firing temperature of 750°C for 2 hours is optimal, yielding 86.8%* Al_2O_3 *extraction with reduced dust removal (8.5–10%) compared to fluidized bed kilns. The findings confirm the feasibility of rotary kilns for efficient kaolin clay processing with lower dust emission and simpler dust collection requirements.*

Keywords: *Aluminum oxide extraction, nitric acid leaching, kaolin clay dehydration, rotary kiln firing, fluidized bed furnace, calcination temperature, alumina-containing raw materials, Angren kaolin, substandard bauxite, dust removal, fuel oil consumption, acid-soluble alumina.*

Tubular rotary kilns are used for the thermal treatment of finely crushed bulk materials without melting them. In most cases, they consist of a long pipe made of heat-resistant materials, inside which the processed material and hot gases typically move in counter-parallel directions. The pipe is inclined, causing the particles of the heated material (charge) to rise to a small height, fall, and shift downward when rotated. As the charge moves through the pipe, it mixes, resulting in uniform heating of each particle. The material receives additional heat from the heated furnace body.

Due to their high heat exchange coefficient between fuel combustion products and the heated substance, tubular furnaces have found wide application in various production processes. They are used to dry materials, removing chemically bound moisture. In tubular furnaces, various substances are sintered to create new materials. Such devices are indispensable in metallurgy, for processing alumina (sintering and calcination) in the process of aluminum production.

A classic example of a tubular rotary kiln is one designed for sintering bauxite - a material containing aluminum. The kiln consists of several main components:

- drum;
- rotation mechanism;
- roller-type supports;
- burner head;
- feed chamber.

The main component of the kiln is the rotating drum. Its diameter can range from 2 to 3.8 m, and its length can reach up to 150 m. The drum is lined with bricks. High-alumina or fireclay bricks are used for the lining.

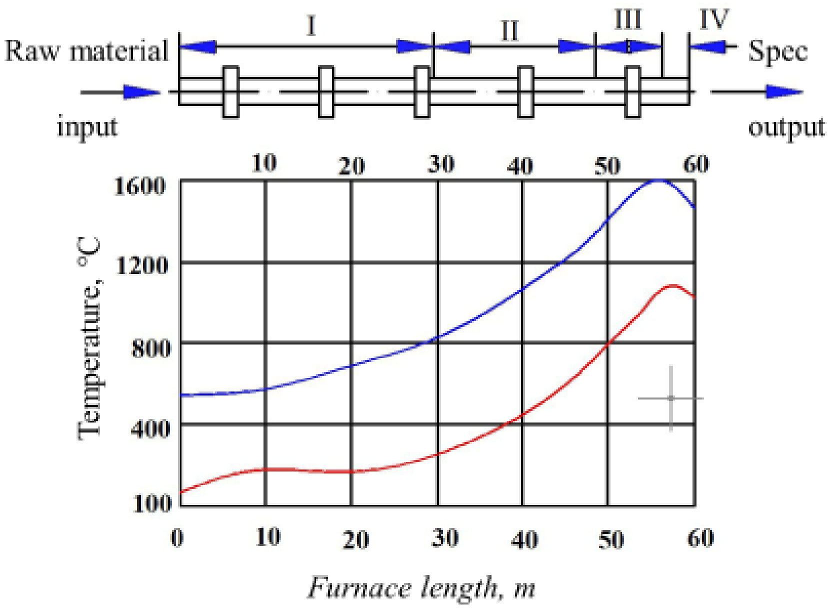

Fig-1. Thermal balance of the furnace.

When examining the temperature graph of the drum, four areas with similar characteristics can be identified. The main sections are:

- drying zone;
- calcination zone;
- sintering zone;

- cooling zone.

The heated material, known as the charge, in dry or moisture-saturated (40-42%) form is fed into the upper (cold) chamber. As the kiln rotates, the charge slowly moves towards the lower (hot) end. Simultaneously, combustion products rise from below, drying and sintering the material. The sintered product, called "sinter," reaches the lower end of the tube and is discharged into a cooler located beneath the rotating kiln.

The cooler is designed as a drum up to 30 m long, with an internal diameter of up to 2.5 m. Inside the cooler, the sinter is cooled by an incoming air stream or by water streams that spray the drum. In the case of air cooling, the heated air is directed back to the kiln, optimizing the fuel combustion process, which significantly increases the kiln's efficiency.

Natural gas, fuel oil, and coal dust can serve as fuel for furnaces. The chamber with burners or nozzles is located at the lower end of the furnace. Exhaust gases undergo several stages of purification before being discharged into the chimneys. They are directed to dust collection chambers, passing through several electrostatic precipitators.

The prepared and loaded furnace has a very large mass. For example, the total mass of a furnace with a drum 70 m long can reach 400 tons. To support the drum and ensure its rotation, special bandages are used that encircle the furnace shell. The support function is performed by rollers installed on rolling bearings.

The rotation of the drum is carried out by a motor. The force is transmitted through a gearbox to the ring gear fixed to the drum housing. The rotation speed can be regulated and typically ranges from 0.6 to 2 revolutions per minute.

The furnace is installed at an angle to the horizontal. The angle is between 3 and 6%. To prevent the structure from shifting under its own weight, thrust rollers are used. They are placed horizontally, with the bandages pressing against them from the side. The lower (2) hot end of the drum is connected to the fuel head. There is also a channel through which the clinker is poured into the cooler. For ease of operation, the fuel head is retractable. The drum is separated from the fuel chamber by a labyrinth seal. It is a disk rotating in a box with holes for nozzles.

The cold (upper) end of the drum is connected to the loading chamber. A rigid pipe is used for loading dry charge. The liquid slurry is drained or sprayed using nozzles. To prevent the charge from caking, the loading chamber is equipped with a special deflector. It is a steel dummy (weight) suspended on a flexible suspension (chain). During the rotation of the drum, the weight swings, breaking up the caked material.

In order to achieve the most complete extraction of aluminum oxide during nitric acid leaching of kaolin clays, it is necessary to perform their dehydration at a temperature above 600°C. Previously, on a pilot plant scale, a firing method in a fluidized bed furnace was tested, which showed that up to 87% of aluminum oxide in the raw material can be converted to an acid-soluble form at a firing temperature of 750°C and a process duration of 2 hours. However, granulation of small clay fractions (up to 25-30% of the mass) is mandatory, while increased requirements are imposed on their granulometric composition, and the need arises for organizing a large dust collection system. All this indicates that the method of rock dehydration in a rotary kiln requires verification.

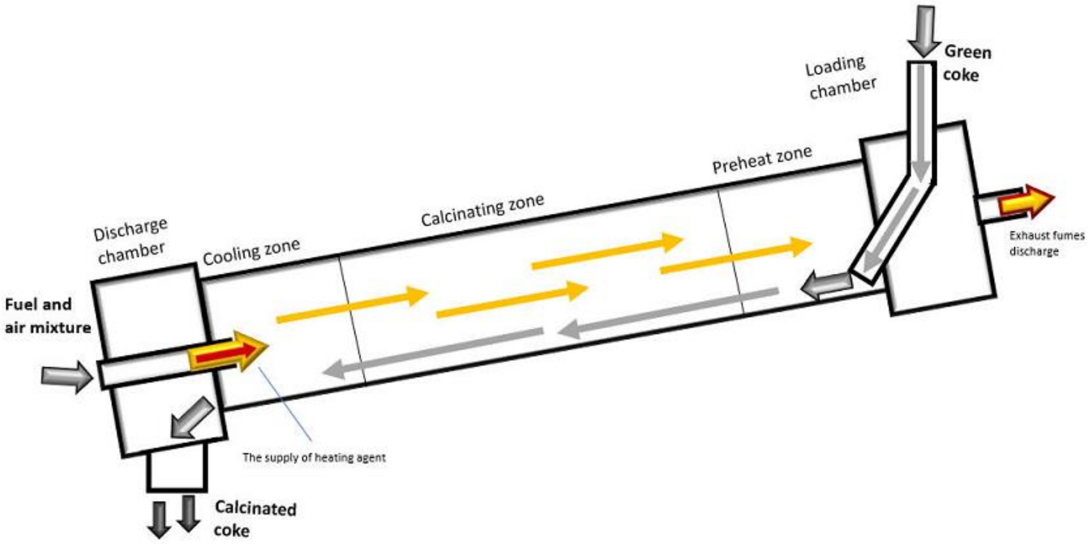

Fig-2. Rotary tubular kiln.

Large-scale factory firing experiments were conducted using a 12-meter rotary kiln with a diameter of 1 m, rotating at a speed of 1-0.5 rpm, equipped with an external furnace (figure). The kiln lining was made of heat-resistant cement, and fuel oil was used as fuel. 25 tons of unenriched kaolin clay (22.4% Al_2O_3) from the Angren deposit with particle sizes of 2.5 mm and 5 tons of substandard bauxite (30% Al_2O_3), in which up to 30% of aluminum oxide is present in the form of kaolinite, were fired. The firing temperature varied from 600 to 800°C, with the material's residence time in the furnace ranging from 1 to 2 hours. During the firing process, the temperatures of the furnace gases, exhaust gases, and the middle zone of the furnace were recorded. The temperature was regulated by adjusting the fuel oil flow rate, which, when converted to conventional fuel, amounted to 0.15-0.2 t/t of material.

The furnace was loaded using a plate feeder, while the exhaust gases were directed to a cyclone system. Samples of the calcined product underwent control leaching.

The firing results are presented in the table, which also includes comparative data on the firing of alumina-containing raw materials under fluidized bed conditions for comparison.

Data on the firing of alumina-containing raw materials in a rotary kiln:

Temperature °C	Duration, hour	Product yield, %		Extraction Al_2O_3, %		Dust removal %	
		FB	Speech-rotating	FB	Speech-rotating	FB	Speech-rotating
600	2	-	79,5	84,1	83,5	-	8,5
650	2	-	79,3	84,0	84,0	-	8,7
700	1	-	78,4	84,7	82,5	-	9,6
700	2	-	78,7	84,4	84,3	-	9,3
750	1	-	77,9	85,2	84,2	-	10,1
750	2	65.4	78,2	82,5	86,8	17,2	9,8
800	2	65.4	78,8	86,8	81,7	25,7	10,2

The table shows that a temperature of 750°C and a firing duration of 2 hours are optimal. This confirms the previously obtained laboratory data. A reduction in firing temperature leads to incomplete dehydration of the material, while at temperatures above 800°C, over burning occurs, which sharply reduces the extraction of Al_2O_3. Dust removal during firing in a rotary kiln is 8.5-10%, which is 2-3 times lower than the dust removal in a FB kiln. This circumstance, combined with the low velocity of exhaust gases, allows for a very small dust collection system to be sufficient.

When reintroducing the dust into the total mass of the fired material, the product yield was approximately 90%. This the scaled-up pilot plant studies demonstrated the feasibility of efficiently firing kaolin clays in a rotary kiln.

CONCLUSION:

Tubular rotary kilns play a crucial role in the thermal processing of bulk materials, offering efficient heat exchange and controlled sintering conditions. Their application in metallurgy, particularly in alumina production, has proven effective due to their ability to uniformly heat materials and optimize fuel consumption.

Experimental studies on firing kaolin clays in a rotary kiln confirm that a temperature of 750°C with a 2-hour duration yields the highest aluminum oxide extraction rates while minimizing dust loss. Compared to fluidized bed furnaces, rotary kilns demonstrate superior efficiency in reducing dust emissions and ensuring optimal material transformation with lower energy consumption. These findings reinforce the viability of rotary kilns for large-scale industrial applications, providing an effective and economically feasible solution for alumina-containing raw material processing.

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