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Design of Drying Drum for Use in Processing Gypsum-Bearing Waste

S. I. Antsiferov[a, *], A. V. Karachevtseva[a, **], S. Yu. Pirieva[a, b, *], N. I. Kozhukhova[a, b, ****], and N. I. Alfimova[a, c, *****]**

[a] *Belgorod State Technological University Named after V.G. Shukhov, Belgorod, 308012 Russia*
[b] *Belgorod State National Research University, Belgorod, 308015 Russia*
[c] *Tomsk State University, Tomsk, Russia*
**e-mail: anciferov.sergey@gmail.com*
***e-mail: karachevtseva.anastasiia@gmail.com*
****e-mail: p-sevda@mail.ru*
*****e-mail: kozhuhovanata@yandex.ru*
******e-mail: alfimovan@mail.ru*

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Abstract—Gypsum-bearing waste has value for the production of construction materials, resource extraction, and agriculture. However, its unstable composition prevents the development of a single comprehensive approach to processing such waste. The design of a drying drum is discussed for a line capable of comprehensive processing of gypsum-bearing waste from various industrial enterprises.

Keywords: gypsum-bearing waste, waste processing, thermal balance, material balance, dehydration, drying drum, reference structure, CAD/CAM/CAE system

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At present, numerous enterprises are generating large quantities of gypsum-bearing waste. That represents a potential basis for the creation of commercial products [1–5].

The processing of gypsum-bearing waste is of great interest currently not only to researchers but also to industrial enterprises [2]. The simultaneous derivation of multiple products is the most promising, in economic and practical terms. That approach shrinks waste stockpiles, minimizes economic risk, and ensures profitability [5–7].

In contrast to a natural raw material, gypsum-bearing waste does not have a stable chemical or granulometric composition. That complicates the use of classical approaches to processing.

The production of gypsum binder by roasting when the initial waste contains 5–20% moisture calls for specific thermal treatment. Drum dryers are generally used, with working temperatures up to 200°C [8].

METHODS

The design of drying drums involves the following stages.

1. Calculation of the fuel combustion to determine the air flow rate required, the quantity and composition of the combustion products, and the combustion temperature. The combustion temperature is found from the balance between the heat introduced by the fuel and air and the heat of the combustion products. The air flow rate and product yield are determined from the material balance of the combustion process [9].

2. Calculation of the material balance from the required productivity and determination of the quantity of water evaporated. The material balance must correspond to mass conservation. In particular, the mass of the initial material in the physicochemical reaction must equal the mass of the final products, including the material losses. The items in the balance correspond to the unit mass consumption of each component (kg/kg of product).

3. Calculation of the thermal balance. According to the thermal balance of the drying drums, the heat released in drying must be equal to the sum of the heat consumed in the process (and the useful heat) and the heat lost to the atmosphere. In other words, the thermal balance corresponds to the law of energy conservation.

4. Determination of the basic technological and design parameters. The following factors are determined: the drum speed n, the time τ for the material to pass through the drum, the drive power N, the vapor removal A, and the working volume V of the drum.

5. Digital design of the drying drum in the NX CAD/CAM/CAE system. Some stages—such as the

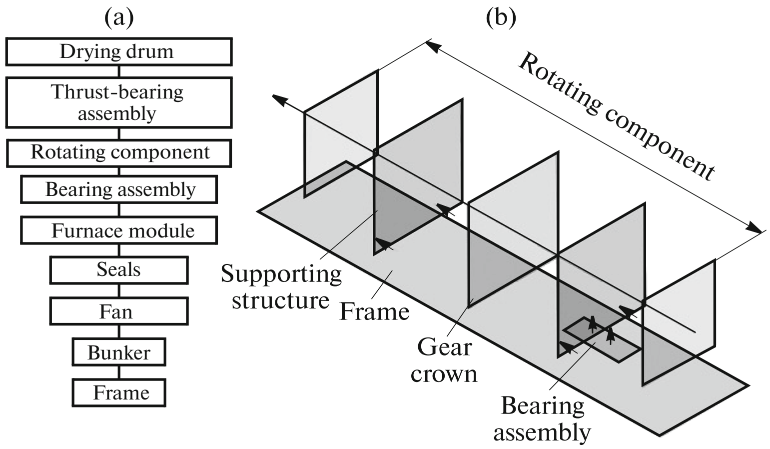

Fig. 1. Simplified (a) and reference (b) structure of drying drum.

calculation of the fuel combustion, the material balance, and the thermal balance—are the responsibility of technologists. The results are given to the designers so as to determine the basic drum parameters: the speed n, the time τ, the power N, the vapor removal A, and the volume V.

The digital design of the drying drum in the NX CAD/CAM/CAE system employs integrated software for the design, preproduction, and practical analysis of engineering systems, with a powerful functional for the development of a competitive product. In production, the NX system is integrated with the Teamcenter PLM system, covering all stages in the product life cycle [10, 11].

RESULTS

The first step in the design of a drying drum is the creation of a preliminary product structure, which is then used to formulate the product's electronic structure and to distribute tasks among the designers. In Fig. 1a, the drum structure is shown in simplified form.

The drying drum consists of several subassemblies such as the rotary component, the bearing structures, the furnace module, the seals of the drum input and output, the fan, the bunker, and the frame.

The next step is to create the reference structure of the assembly, consisting of geometric elements such as planes and axes in specific configurations (Fig. 1b). By means of the reference structure, changes in the product may be developed and introduced more rapidly [10].

In digital design, we assume direct flow through the drum. In direct flow, the drying agent is at higher temperatures in the initial stage of the process. That results in more intense drying, with maximum vapor removal [9].

The digital model of the drum consists of inclined frame *1*, to which the bearing *2* and thrust-bearing *3* assemblies are attached (Fig. 2). The rotating component *6* is mounted on the supporting rollers of these assemblies. Seals *7* mounted at the input and output of the rotating component limit air leakage and hence decrease the heat losses. The hot end of the dryer is connected to furnace module *8*, while the cold end (with discharge bunker *4*) is connected to fan *5*. To prevent spilling of the material in the furnace module onto the cold end of the rotating component, helical blades are installed.

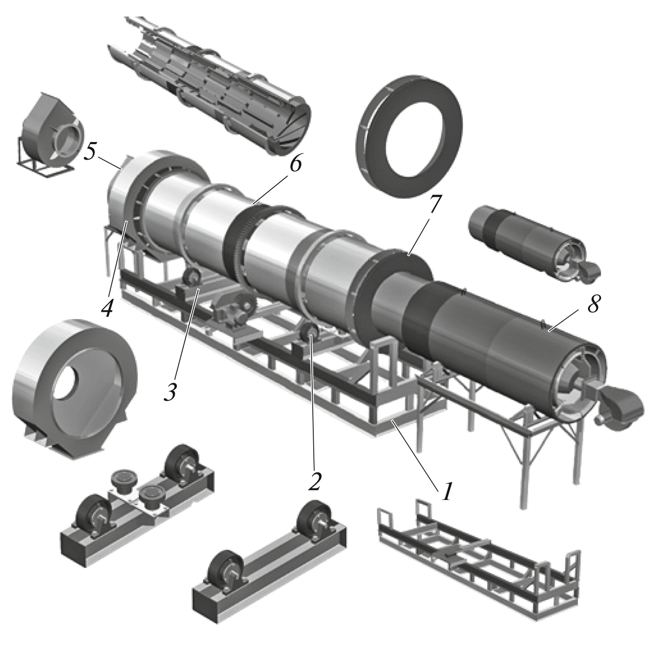

Fig. 2. Digital model of drying drum: (*1*) inclined frame; (*2*) bearing frame; (*3*) thrust-bearing frame; (*4*) discharge bunker; (*5*) fan; (*6*) rotating component; (*7*) seal; (*8*) furnace module.

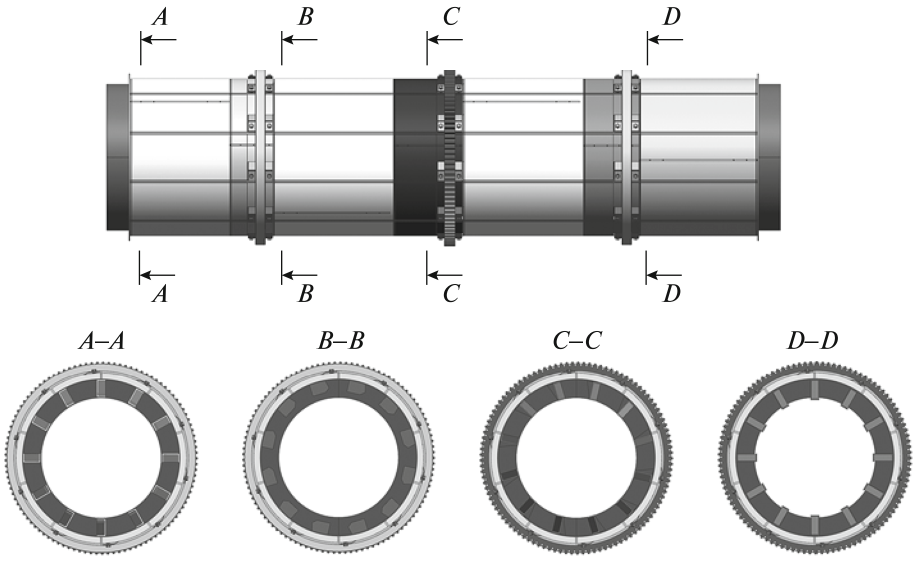

Fig. 3. Vane-type heat exchanger.

The interior of the drum consists of vane-type heat exchangers, which increase the contact of the material with the drying agent, thereby improving heat transfer and intensifying the drying process [8] (Fig. 3). The vanes capture the dried material and raise it to a specific height. That scatters the particles over the whole drying area within the drum, thereby increasing their contact area with the drying agent.

Once the digital model of the drum has been developed, we check for the presence of intersections; the NX CAD/CAM/CAE system verifies the configuration of the subassemblies (their contact, intersection, gaps).

The next step is to generate the design documentation, which includes the following requires: (a) manual arc welding in accordance with State Standard GOST 5264–80; (b) casting of the dryer components in accordance with State Standard GOST 977–88; (c) no more than ±0.5% deviation of the external housing diameter from the rated drum diameter; (d) noncircularity of the housing at the supports, crown, and seals amounting to no more than 0.5% of the rated drum diameter; (e) gear precision (engagement of the pinion and crown) in accordance with class 10-A of State Standard GOST 1643, with verification of the precision for all the elements in the working drawings; (f) hardness of the pinion teeth no less than 240 *HB*; (g) extremely careful positioning of the components in drum assembly, with no surface damage (no dents or scratches).

CONCLUSIONS

1. We have outlined the main stages in design of drying drums for use in processing gypsum-bearing waste.

2. The proposed approach to the design of drying drums leads to a shorter process, with less likelihood of errors. Digital design reduces the manufacturing cost of the drying drum by permitting timely changes in the design.

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CONFLICT OF INTEREST

The authors declare that they has no conflict of interest.

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