ISSN 1068-798X, Russian Engineering Research, 2023, Vol. 43, No. 1, pp. 88–90. © Allerton Press, Inc., 2023.
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Hybrid Drying-Drum Seals

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Received May 21, 2022; revised May 21, 2022; accepted May 21, 2022

Abstract—Drying drums are important for drying and roasting operations in the preparation of construction materials. To increase their efficiency and reduce the energy consumption in heating, their seals may be improved. To that end, the design of various seals is analyzed, highlighting their advantages and disadvantages. A digital twin of the drying drum is used in developing a hybrid seal. The operating principle of the hybrid seal is considered, and the problems that the new design resolves are noted.

Keywords: drying drum, drying, sealing, dust extraction, digital twin, heat losses, spring mechanism, gypsum-bearing wastes

DOI: 10.3103/S1068798X23020053

INTRODUCTION

Drying drums are used in the production of binders—in particular, gypsum—to dry and roast materials. The drum has large gaps at its loading and unloading ends, through which air is sucked in from outside [1]. Energy is mainly consumed in heating the drum and setting it in motion. To reduce the costs, the following design improvements are introduced: the costs in preparing the desiccant are decreased by intensifying heart and mass transfer; the drive's power consumption is decreased; and new seals are designed [2].

Seals are mounted at the ends of the drum to prevent the intake of external air and increase the drying efficiency. The incoming air cools the seal and also the loading and unloading ends of the drum. Complete elimination of the air intake leads to high temperature of seal and drum components and may lead to their deformation and failure [3].

The design of a drying drum in the line for processing gypsum waste at industrial enterprises was considered in [4]. In the present work, we improve the drum design by developing a hybrid seal.

MATERIALS AND METHODS

In the first stage, we analyze existing seals, identifying their advantages and disadvantages. In the second, we design a hybrid seal on the basis of the theoretical findings.

Digital design of the drying drum and hybrid seal employs the NX CAD/CAM/CAE system.

TYPES OF SEAL

Several types of seal are used for drying drums. The most common are labyrinthine, skirt, and spring seals.

1. Labyrinthine Seal

The labyrinthine radial seal of a drying drum (Fig. 1a) consists of drum *1*, chamber *2*, immobile rings *3*, mobile rings *4*, annular support *5*, to which mobile rings *4* are rigidly attached (perpendicular to its external surface), and annular support *6*, to which immobile rings *3* are rigidly attached (perpendicular to its internal surface). Annular support *5* is attached to the drum by unit *7*, which includes a pin, a washer, and a nut, while support *6* is attached to chamber *2* by an analogous unit *8*. Elastic ring *9* with an external film *10* of antifrictional polymer is attached to the side of

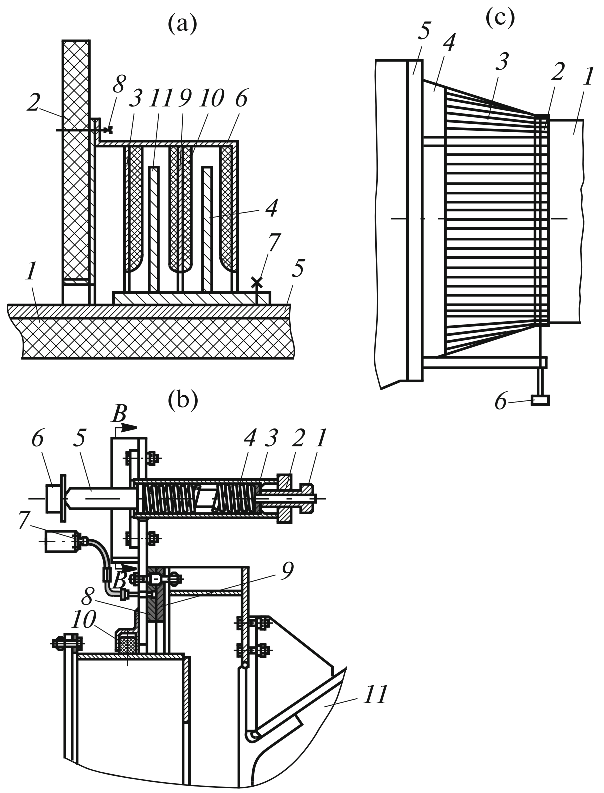

Fig. 1. (a) Labyrinthine seal: (*1*) drum; (*2*) chamber; (*3*) immobile sealing ring; (*4*) mobile ring; (*5*, *6*) annular supports; (*7*, *8*) removable units; (*9*, *11*) elastic rings; (*10*) film; (b) spring seal: (*1*) control bolt; (*2*) spring support; (*3*) pressure module; (*4*) spring; (*5*) upper module; (*6*) upper saddle; (*7*) lubricant supply mechanism; (*8*, *9*) immobile and rotating sealing rings; (*10*) sealing module; (*11*) housing; (c) skirt seal: (*1*) housing of machine; (*2*) beads; (*3*) flexible elements; (*4*) cone; (*5*) cooling unit; (*6*) load.

each immobile ring *3*, adjacent to the side of mobile ring *4*. Likewise, ring *4* is coated with a film *11* of antifrictional material [5].

This seal operates as follows.

In the rotating drum, low pressure prevents the loss of hot desiccant. The air outside the drum is drawn inside through the annular gaps between the immobile and mobile rings, which form a labyrinthine radial seal.

Important benefits of this seal include the following.

1. The lack of mechanical contact between the rotating components minimizes the wear and hence the frequency of maintenance and repair.

2. Because there is no need for other components, operation is simple, and the frequency of fracture and replacement of parts is low.

3. The rotating and motionless components are separated by a minimal gap of complex configuration, regardless of the type of device (step device, direct-flow system).

2. Spring Seal

For the rear of the drum, the seal employs a spring whose support includes a control bolt, which connects the spring to the clamping unit (Fig. 1b).

The seal contains a spring control mechanism, immobile sealing ring *8*, and rotating sealing ring *9*. The control mechanism contains an upper saddle *6*, upper module *5*, spring *4*, and spring support *2*. The upper saddle is coupled to the upper module. The spring is mounted on the spring support, to which the upper module is connected. The spring control bolt *1* of the spring support is connected to the spring by clamping unit *3*. The immobile sealing ring is mounted at the end of the furnace. The rotating sealing ring is installed in machine housing *11*. The immobile and rotating sealing rings are in relatively tight contact. The spring control mechanism is connected to the immobile sealing ring so as to adjust the immobile and rotating sealing rings.

The rotating sealing ring is in close contact with the gap. The immobile and rotating sealing rings are equipped with mechanism *7* for supplying lubricant to the corresponding sealing contact. The rear of the machine is equipped with sealing module *10*, while the position of the sealing module corresponds to the immobile sealing ring.

Benefits of this seal include the following: (1) improved reliability and so fewer accidents; (2) lower maintenance costs; (3) greater productivity. Disadvantages include the following: (1) high cost; (2) tendency to stick; (3) repair complications.

3. Skirt Seal

The operating principle of the skirt seal is relatively simple (Fig. 1c). Flexible skirt elements are attached to a ring mounted on the machine's housing. A suspended load presses these elements against the machine housing, thereby reducing the heat losses and dust entrainment from the drying drum. This seal is placed at the cold end of the machine.

Benefits of this seal include the following: (1) simple manufacture; (2) less metal consumption than in other seals; (3) easy replacement of skirt elements. Disadvantages include the following: (1) frictional destruction of the seal surfaces resting on the machine's housing; (2) deformation and failure of the skirt elements under the action of the tension applied and corrosion of their internal surface; (3) incomplete sealing on account of the gaps between the elements; (4) short seal life (no more than a year). The skirt seal remains operative for a long time and prevents the intake of external air and dust emissions [1].

Thus, we need to improve the performance of seals in industrial equipment by improving their design [6].

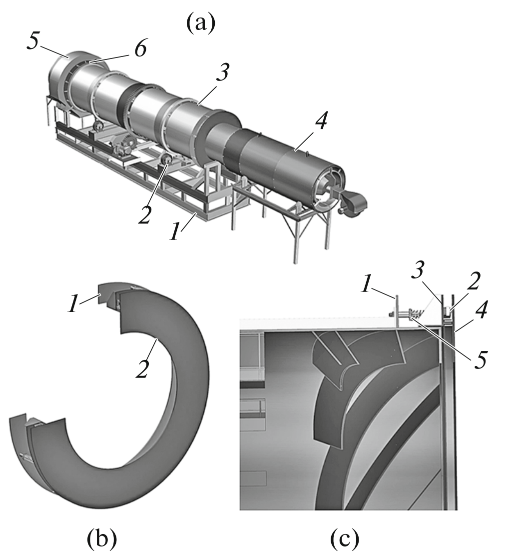

Fig. 2. (a) Digital twin of drying drum: (*1*) frame; (*2*) support; (*3*) housing; (*4*) furnace module; (*5*) bunker; (*6*) hybrid seal; (b) hybrid seal: (*1*) mobile half; (*2*) immobile half; (c) mobile half of hybrid seal: (*1*) flange; (*2*) roller; (*3*) shell; (*4*) immobile half with labyrinthine channels; (*5*) spring mechanism.

NEW SEAL DESIGN

Therefore, in studying standard approaches to preventing air intake, the following requirements on seal design have been established: low metal content, prevention of dust emission, and ease of repair.

We also draw the following conclusions.

1. Hybrid seals are most commonly used for drying drums.

2. Combinations of labyrinthine and skirt seals predominate.

3. The key feature of such designs is constant sealing with axial motion of the drying drum.

We adopt those features in our seal design.

The new seal design (Fig. 2a) is developed on the basis of a digital twin of the drying drum, created using Siemens NX automated design software. The drying drum consists of a frame *1*, on which is mounted a support *2* bearing the housing *3*. The hot end of the drum housing is connected to furnace module *4*. The cold end is connected to bunker *5*. To prevent the intake of external air, new hybrid seals are installed at the drum housing.

The hybrid seal (Fig. 2b) consists of two halves: one is mobile and the other is immobile. The mobile half *1* is attached to the drum housing, while immobile half *2* is mounted on the furnace module and the bunker.

The immobile half (Fig. 2c) is soldered by flange *1* to the housing and connected to shell *3*. Labyrinthine channels connect shell *3* with the immobile half through roller *2*. The gap between the labyrinthine channels of the seal is regulated by spring mechanism *5*.

This hybrid seal permits axial motion of the drying drum while maintaining a uniform gap between the labyrinthine channels and constant force exerted by the housing on the seal in linear expansion. Deformation of the seal components is ruled out.

CONCLUSIONS

1. We have identified means of improving the seals of drying drums so as to decrease the intake of external air.

2. By means of a digital twin of the drum, we have developed a hybrid seal such that the drying efficiency is increased with minimal metal consumption.

FUNDING

Financial support was provided within the framework of the state project for the creation of new laboratories in 2021, including laboratories directed by promising young scientists, as part of the National Plan for Science and Universities, with the specific goal of developing scientific and technological principles for the processing of gypsum-bearing waste from various industrial enterprises (FZWG-2021-0017). Administrative support was provided by the Research Center on Innovative Solutions in Industrial Agriculture, Belgorod.

CONFLICT OF INTEREST

The authors declare that they have no conflicts of interest.

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Translated by B. Gilbert