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CONSTRUCTIVE SOLUTION TO ELIMINATE AIR LEAKS AND DUST EMISSION IN THE INLET AND OUTLET OF A KILN

Julia Anatolievna Bondarenko, Mikhail Alekseevich Fedorenko, Tamara Mikhailovna Canina, Nadezhda Savelievna Sevryugina and Olga Vasilievna Markova
Belgorod State Technological University named after V.G. Shukhov, Russia, Belgorod, Kostyukova Street, 46.

ABSTRACT

Design features of the lamella seal of cement kiln. Calculation of contact surface wear beads reduced by increasing the area of its contact with the kiln body, and applying a "light" alloy and compression force. Functional relationship between the parameter optimization and investigated factors. Dimensionless equation describing wear beads sealing device according to the major determinants of its design features and influencing its work in conditions of dry friction in the presence of a minor amount of solid lubricant. Determination of the load acting on the friction bead of the sealing device. Lubricant for friction surfaces. Justification of the choice of material friction surface (beads). Study the joint effect of insertion elements of wear on the friction surfaces. Analysis of the impact parameter optimization complexes. Ensuring uniform contact with the sidewall of the furnace sealing and prevent slipping, which will ensure minimum wear of rubbing surfaces and maximum seal life.

Keywords: kiln, air leaks, dust emission, friction, surface design, seal design, rotating machines, wear beads, influence of complex equations, parameter optimization.

INTRODUCTION

Currently, due to the need to save energy, particular attention is drawn to any activities and innovation, leading to lower fuel consumption and energy savings. The cement industry consumes a large amount of energy in rotary kilns with clinker burning [1]. Therefore, special attention is paid to the prevention of air leaks in rotary kilns. Air leaks in the hot end of the kiln reduces the temperature of the secondary air and hence the flame temperature. To compensate for the decrease in temperature, it is necessary to apply an additional amount of kiln fuel which, in turn, increases the load on the fan, fume and dust-collecting equipment cooler. Through the gaps between the fixed head and a rotary kiln discharge end and between the feed end and the wall of the smoke chamber to the kiln chamber and outside air is sucked in, reducing the thermal efficiency of kiln performance [6]. Good seal reducing air leaks, improves operation of the refrigerator, reduces fuel consumption, thereby stabilizing the combustion process and accelerates the burning process [7].

RESULTS AND DISCUSSIONS

In operation, the flap sealing device on a cement kiln in the contact pair of bead - kiln body, a process of wear caused by sliding friction of these surfaces.

In order to reduce the amount of wear of the contacting surfaces and increase their efficiency necessary to create conditions for the process of friction such as depreciation will be minimal. This result can be obtained by reducing the contact stresses, high hardness materials and lubricant applications [2, 3].

In this specific load on the sealing bead can be reduced by increasing the area of its contact with the kiln body, and applying a "light" alloy and compression force.

Increased contact area entails bulkiness and weight design seals.

The use of "light" alloys for making beads requires the creation of conditions to ensure minimal wear. This question is solved by applying lubrication and increased hardness of the alloy.

Given that liquid and grease on cement kilns can't be applied because of the large amount of dust, you need to place in the body beads solid lubricant.

High hardness "light" alloys can't be obtained, hence improve the overall hardness of the surface of the beads can be achieved by introducing into it inserts of solid materials [4]. In general, a priori information on the basis of the wear surface of friction can be represented as:

$$И = f(P, V, t) \quad (1)$$

where P and V have a dependence, p^m, V^n.

Exponent m and n take into account the type of wear.
Thus, we can write:

$$И = p^m V^n t \quad (2)$$

where P - load on the bead;
V - velocity of sliding surfaces;
t - operation time of the seal.

This equation (2) takes into account only the three main factors, but the amount of wear affects a number of factors inherent in the considered design of the sealing device.

On the amount of wear of the friction surfaces is greatly influenced by the contact area. In the sealing arrangement of the contact surface perimeter length is constant, therefore, the size of the area of friction can be changed due to its width. From the above analysis, it occurs at dry friction heat generation; therefore, the calculation of beads to wear must be considered thermal conductivity and heat capacity [5]. Introduction insertion elements of hard steels affect the amount of wear of the friction surfaces. Changing the magnitude of the dimensions can be adjusted inserts wear contact surfaces bead - kiln body. Therefore, the equation of wear should include value size inserts for this in the equation, we introduce an aspect ratio of the total area of the beads to the largest square inserts $\frac{H_o}{H_c}$, where H_o - the total area of beads, H_c - the area of steel inserts [6].

To improve the conditions of friction in this seal must enter the grease. In the estimated equation must enter data, taking into account the amount of lubricant $\frac{H_c}{H_\Gamma}$, where H_Γ - the value of the area of lubrication.

As a result, we obtain the dependence of wear beads of the main factors:

$$И = f\left(P, V, в, t, \lambda, c, \frac{H_o}{H_\Gamma}, \frac{H_o}{H_c}\right), \tag{3}$$

So obtained the functional dependence between the parameter optimization (wear mass, g) and investigated factors.

We write the equation of similarity:

$$\frac{И}{P} = f_2\left[\left(\frac{Ptc}{в^2\lambda}\right)^{\alpha}\left(\frac{Vt}{в}\right)^{\beta}\left(\frac{H_o}{H_\Gamma}\right)^{\gamma}\left(\frac{H_o}{H_c}\right)^{\xi}\right]. \tag{4}$$

According - Theorem, the number of combinations of dimensionless complexes equal to the difference between the amount of physical quantities and base units dimension, ie $K = \Phi - P = 8 - 4 = 4$.

We represent the function (4) as a solid row [7]:

$$\frac{И}{P} = a_0\left(\frac{Ptc}{в^2\lambda}\right)^{\alpha}\left(\frac{Vt}{в}\right)^{\beta}\left(\frac{H_o}{H_\Gamma}\right)^{\gamma}\left(\frac{H_o}{H_c}\right)^{\xi}, \tag{5}$$

where a_0 - constant, reflecting the impact on unrecorded factors.

Hence, the equation takes the form of wear beads:

$$\frac{И}{P} = e^{x}\left(\frac{Ptc}{в^2\lambda}\right)^{\alpha}\left(\frac{Vt}{в}\right)^{\beta}\left(\frac{H_o}{H_\Gamma}\right)^{\gamma}\left(\frac{H_o}{H_c}\right)^{\xi}, \tag{6}$$

where the coefficients [alfa], [beta], [gamma], [ksi] take into account the type of wear.

Obtained criterion equation (6), describing the wear beads sealing device according to the major determinants of its design features.

The equation includes the ratio of the areas $(\frac{H_o}{H_\Gamma}, \frac{H_o}{H_c})$, these parameters are specific to a given equation.

Equation (6) involves a combination of complex combinations of key factors influencing the friction surface wear beads in terms of cement kiln. Most available for varying the value $\left(P, V, t, H_o, H_\Gamma, H_c\right)$ allow to perform such design beads, which is optimal in terms of work for a cement kiln certain diameter [8].

Obtained criterion equation (6), which describes the friction surface wear beads daisy seal depending on the major factors influencing its work in conditions of dry friction in the presence of a minor amount of solid lubricant.

Equation allows us to choose the quantitative factors to ensure long-term performance of the sealing device.

It is established that as the friction surfaces is necessary to use an aluminum alloy. Beads made of such an alloy has a weight of *700 g* and 3 times lighter than steel, it reduces the weight of the sealing device.

From the analysis it was established that the proposed sealing lobes can be made of steel *0.8 mm* thick.

Statistical data revealed that the length of the petals on similar seals is within *450...600 mm*, width *150...200 mm*.

Based on the above data, we find that the mass of the considered sealing device is *100...150 kg* depending on the diameter of the kiln, i.e. the amount of flexible elements.

The bottom seal part (Figure-1) has a weight of *75 kg*, and under the influence of gravity moves from the kiln body is therefore sufficient to exert a traction rope force of *800 N*, to urge the seal to the shell of the kiln.

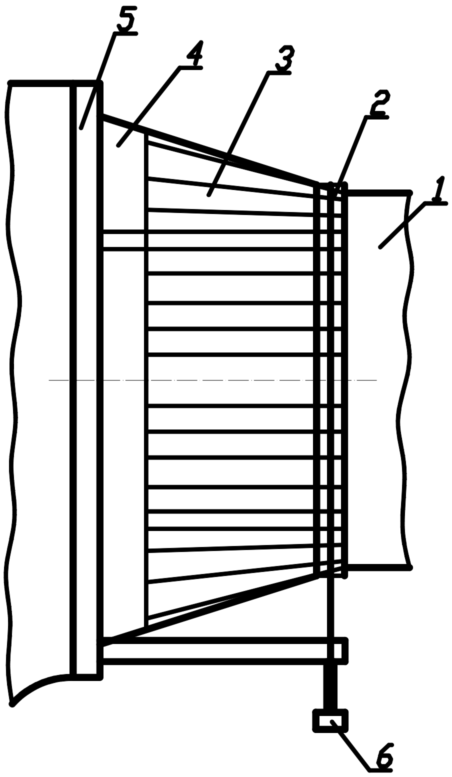

Figure-1. Sealing device:
1 - kiln 2 - beads 3 - flexible elements 4 - cone
5 - cooler, 6 - load.

In cement kilns, not because of improvement, occur locking gas channels resulting in the discharge end of the pressure rises to *5333 Pa* and gases are ejected through the gap under seal. Gas pressure creates a load on the sealing surface and separates it from the furnace body. On the kiln *5 m* in diameter with increasing pressure to *5333 Pa* with a length of 0.5 m petal seal on the force in *2984 H*, respectively, for the furnace diameter of *3 m - 1898 N*.

To prevent detachment of the seals from the furnace body, while increasing the pressure at the discharge end, to cables, tightening the elements of the upper and lower seal portion, it is necessary to suspend a weight of *90...150 kg* depending on the diameter of the furnace.

Based on the flexibility and mobility of the seals as well as design considerations may be taken lobe width of *250 mm*, then the bead is of the same length. Width beads can take *60 mm* based on the fact that it is located tightening rope, steel inserts and grease.

Consequently, the maximum load on the friction surface will be within the $20...33\ H/cm^2$ depending on the tightening of goods.

Currently, the cement industry has a furnace diameter from *3.5m* to *7m*. Their speed ranges from *1.2* to $1.6\ min^{-1}$, hence, the linear speed of the housing of the rotary kiln is in the range *13...35 m/min*.

Up search experiments provided test a variety of materials as well as aluminum alloys, with limited slip velocity under dry friction up to 120 *m/min*.

The main requirements for lubricants are: reduction of friction forces, reduced wear, cooling parts, corrosion protection, ensuring tightness friction unit, continuous cleaning of surfaces [2].

Despite the great availability of lubricants, applying them to the rotary kiln sealing impossible. The friction surfaces and seals operate in open pollination conditions, i.e. liquid lubricants melt, and soft - clogged with dust emitted from the furnace.

Currently, there are many types of solid lubricants: organic and inorganic compounds, structural and compositional etc. [4].

However, it is necessary to highlight the mixture of solid lubricants with binding to facilitate their application to the work surface, and new anti-friction lubricant obtained by mixing, the main representative of which are metallografitnye materials [2]. According to the theory R. Sevedzha, graphite has no effect on the friction surfaces of steel, if the air is dehumidified and lubricates them if moisture is present.

On the surface of the friction seal - a furnace body due to high temperature, moisture is not available, i.e. need to introduce an additional element of graphite, which creates conditions for the introduction of graphite in the metal surface. One method of coupling the metal graphite is the presence of adhesive is capable of operating under the conditions existing in the kiln. There are a number of adhesives, operating at high temperatures on the basis of: epoxy rubbers (*K-300, 2-400, EDS-25, BK-16*), silicone rubbers (*VC -2, VC -8*); formaldehyde rubbers (*VC -3, VC -4, BK-13M*). The most widely used adhesive *EMF -250*, operating at temperatures from *-60 ° C* to *+250 ° C*. This adhesive keeps its properties at ambient conditions existing at the discharge end of the kiln.

As filler selected powder graphite brushes type *MG*. These brushes have a low coefficient of friction (*0.2*) and contain copper, which improves conditions for friction.

In order to eliminate contact with the furnace body lobes, a construction of beads, which receives the load from the weight of the petal and used as a friction surface.

Directions in selecting the material used to manufacture the beads may be several. The main condition imposed on friction surface lamella seal is a high wear resistance in the absence of wear of the furnace body.

Small beads of wear can be obtained by use of high hardness steel, but in this case the furnace body will have more wear than the bead, due to its low hardness. The use of steel bead mass increases seal *120 ... 150 kg*, it is necessary to increase the load on cable tightening, which holds onto the deformation under the action of frictional forces. The mass increase due to the sealing beads and steel cable tension causes increased load on the friction surface, and thus - enhanced wear.

Reducing the mass of the beads can be prepared using a "light" metal. Widespread currently received aluminum alloys based on silicon. These alloys have good casting and physical and mechanical properties to ensure the application of the alloy friction pairs with small loads at sliding speeds up to *50...120 m/min*. Therefore, studies were conducted resistance of aluminum alloys to wear and friction in order to make informed choices material beads. Couple bead - furnace body refers to the body with a contact on the part of the cylindrical surface, i.e. classification interface can be attributed to one type of the second group [9].

Belonging mates to a particular type determines how it is based on deterioration in certain conditions. Calculations for wear are the basis for the creation of durable machines. To determine the wear couple in the above conditions requires large material costs, since the test must be carried out on several furnaces and for a long time. It was therefore decided to make a study of wear on the friction machine *2070 CMT-1* so that the experimental data gave a fairly complete picture of wear, depending on the selected factors. Experimental conditions are set such that they correspond to the sealing work in the real world. Program provides testing experiments on various physical and mechanical properties of samples under identical conditions.

During the implementation of the experiments carried out the following measurements: spindle speed, sample weights, sizes and inserts the total area of the samples, the linear mass and wear, loads, total speed, the control of the friction surfaces. Feature of this experiment is small sliding speed and low specific pressure.

The purpose of this study - to determine the optimal size of insertion elements (steel inserts and grease) in bead to ensure minimum wear of the friction surfaces bead - furnace body.

The experiments established that:

- relationships with area $\frac{H_0}{H_Г} > 9$ and $\frac{H_0}{H_c} < 3$ wear is reduced fixed specimen, but active destruction begins rolling, this process is due to an increase in average fixed specimen hardness caused by decreasing the area of lubrication and insertion increase in the area of steel inserts (Figure-2, Table-1);

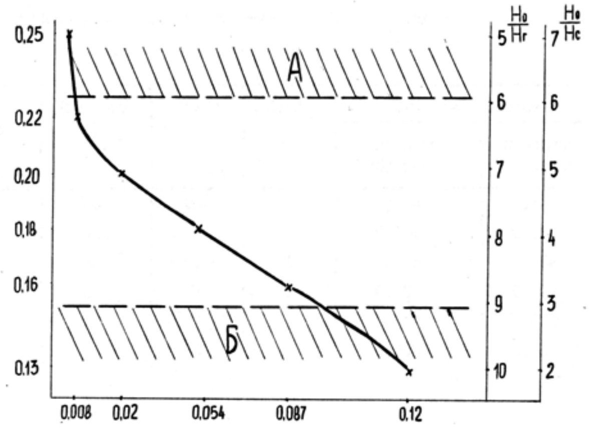

Figure-2. Graph the amount of wear of the friction surfaces, depending on the relationship $\frac{H_o}{H_Г}, \frac{H_o}{H_c}$.

A - zone of active destruction fixed specimen due to the decrease of its average hardness,
B - zone of destruction rolling sample due to the increase of average hardness fixed specimen.

Table-1. Determination of the amount of wear of the friction surfaces, depending on the relationship $\frac{H_o}{H_Г}, \frac{H_o}{H_c}$.

Speed of sliding, V, *(м/мин)*	**Load P,** *(H)*	$\frac{H_o}{H_Г}$	$\frac{H_o}{H_c}$	**Magnitude of wear** (g)	
				movable sample	**Fixed sample**
100	50	10	2	0,134	0,12
100	50	9	3	0,167	0,087
100	50	8	4	0,185	0,054
100	50	7	5	0,204	0,0226
100	50	6	6	0,222	0,0116
100	50	5	7	0,253	0,008

- with respect to the area $\frac{H_0}{H_Г} < 6$ and $\frac{H_0}{H_c} > 6$ wear is reduced rolling sample, but intensively destroyed immobile, it is caused by a decrease in the average hardness of the fixed specimen by increasing the area and reduce lubricant insert steel inserts (Figure-2, Table-1);

- with respect $6 < \frac{H_0}{H_Г} < 9$ and $3 < \frac{H_0}{H_c} < 6$ obtained range of wear of the friction surfaces when there is no intensive destruction of one of them (Figure-2, Table-1), and surface state achieves the best quality for a given pair of friction.

Found that the optimal conditions for the operation of these friction surfaces are outside the area ratios $6 \le \frac{H_0}{H_Г} \le 9$ and $3 \le \frac{H_0}{H_c} \le 6.$ Wear due to the presence of dust up to 8 microns do not increase, and a size of 10 microns - is increasing.

To analyze the effect of complexes equation on optimization parameter values were calculated complexes. Most strongly influenced by complexes $\frac{Vt}{в}$ and $\frac{H_0}{H_c}$. In the course of the experiments was performed varying the value of $\left(P, V, H_c, H_Г\right)$, whose role on the wear process must consider and find their optimum values for creating workable beads.

The simulation process of friction surface wear beads obtained criterion equation. The coefficients ($P, V,$ $\frac{H_o}{H_Г}, \frac{H_o}{H_c}$), taking into account the views of wear, obtained as a result of setting up experiments.

To determine the percent difference amounts of wear obtained experimentally, with the calculated values plotted (Figure-3).

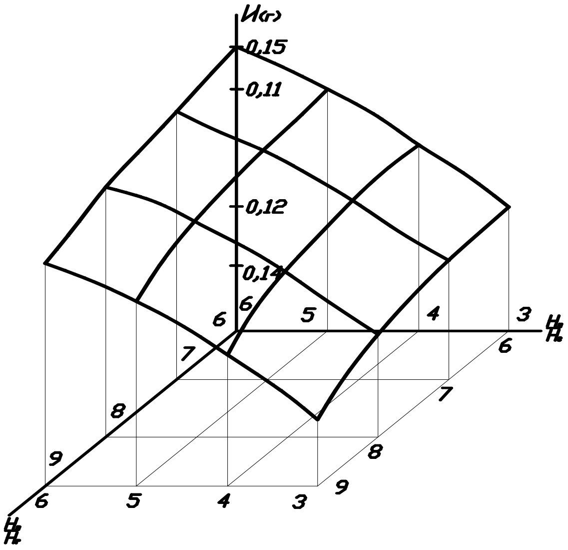

Figure-3. Dependence of wear $\frac{H_0}{H_Г}$ and $\frac{H_0}{H_c} \frac{H_0}{H_Г} \frac{H_0}{H_c}$ in $P = 30\ H$ and V = 35 m/min.

Figure-3 shows a graphical discrepancy between the theoretical calculations and experimental data. For clarity, the graph is constructed to increase the wear and tear, and not the order of the experiments.

In the search for different materials comparative studies of the effect of temperature on the flexible sealing elements with a protective surface layer and without it.

The experiments revealed that under the influence of temperature change galvanized layer is not completely burned, remaining on the surface of the petal *10... 20 microns* layer and penetrates into both the base metal, forming a layer of zinc. In the absence of zinc on the surface of the petal is the destruction of the boundary layer of metal.

Formation of scale leads to destruction of the surface layer (interatomic bonds are weakened in a metal microcracks appear, etc.). With the use of galvanized iron (or galvanized steel) corrosion mechanism changes. The oxidation of the zinc (it passivation) leads to a certain increase in the wear resistance of the surface layer. Moreover, in connection with the penetration of zinc based on the depth of *50 microns* arise guarantee the corrosion resistance of the material.

Thus, the experimentally established and confirmed that the zinc coating is exposed to the gas temperature does not burn completely, as part of the molten zinc penetrates the steel, creating a protective layer. A protective layer of zinc counteracts corrosion of petals, which increases their efficiency up to 5 years.

Consequently, the sealing device for cement kilns should be corrosion-resistant coating.

Application of a zinc coating to prevent sealing lobes corrosion processes damaging the base metal and therefore, they produce a metal thickness of 0.8...1 mm.

In order to prevent air leaks through the gaps between the lobes of the compound must be performed using the slots, it increases tightness and rigidity. In applying the metal thickness of 0.8 mm for reliable sealing performance will affect the load arising from changes in gas pressure at the discharge end of the kiln.

Sealing device made of steel, while the exposed temperature fields, pressure drop, and beats the furnace, i.e. sealing lobes are always under the action of forces caused by these factors. Loss of stability and buckling plates may occur during heating at uniform creep, if the plate is loaded in its plane, the compressive force or, if the offset is limited by any of the circuit connections. In this case the flap is clamped, only one edge, hence there is free to move under the influence of the temperature field.

Given that he is free to move under the influence of the temperature field, the thermal stability of the seal can't be viewed.

The results indicate that the movement of petals are insignificant compared to their size. Stresses arising Bends, will also have small quantities. Consequently, the petal will not collapse under the influence of pressure differences that will ensure the continued operation of the sealing device.

A method for determining the deflection lobe seal incorporates its design features. The inventive method consists in successive refinement of the bending moments acting at the joints adjacent petals. The calculated values of the moments on the edges of the petals of neighboring interference, used to specify the values of deflections and bending moments at the junction.

A disadvantage of the sealing device is the destruction of the contact surfaces due to wear of the friction forces arising. To reduce these effects on sealing devices used some adjustment efforts preload springs or weights.

Device to adjust the value preload surfaces are complex in design and there is no calculation methods to determine the necessary amount of force that ensures minimal wear surfaces with maximum prevention of air leaks. In this sealing arrangement is necessary to ensure the maximum duration of beads with minimal air leak. Figure-4 shows a diagram of the suspension of cargo, which was tested at the factory and model.

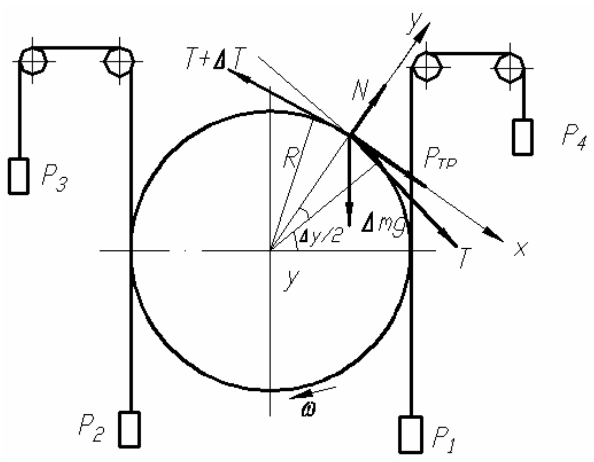

Figure-4. Scheme for calculating the cable tension.

The experiments revealed that the location of goods with separate preload the top and bottom seals proved optimal.

Oven makes uniform radius *R* about a horizontal rotation axis *O* at a constant angular velocity.

The upper half of the seal is pressed against the body of the furnace own weight. To prevent warping petals from the action friction torque followed by a motion of, provided loads P_1 and P_2. Loads P_3 and P_4 balance the bottom half seal, pressing it to the body of the furnace. Then when calculating the cable will be regarded as inextensible yarn with a uniform density.

The proposed method of calculating the weight of goods allows you to find the optimum balance between cargo necessary to ensure uniform contact with the sidewall of the furnace sealing and prevent slipping, which will ensure minimum wear of rubbing surfaces and maximum seal life.

CONCLUSIONS

Violation of the firing and drying of bulk materials occurs when the choke outside air as a result of damage or lack of sealing device. Developed and investigated seal designs [10...13], the optimum of which are installed on the rotary cement kilns.

Application of technology upgrading and increasing efficiency of bulk materials production equipment in operation is of great economic importance.

Developed technologies and equipment allow you to save energy, increase production, improve the life of the equipment.

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