Middle-East Journal of Scientific Research 18 (10): 1448-1454, 2013
ISSN 1990-9233

DOI: 10.5829/idosi.mejsr.2013.18.10.7092

The Power Consumption Calculation of a Ball Drum Mill

Vasily Stepanovich Bogdanov, Sergey Igorevich Antsiferov
and Nikita Eduardovich Bogdanov

Belgorod State Technological University named after V.G Shukhov,
46 Kostukova str. Belgorod 308012 Russia

Abstract: Ball drum mills area commonplace in grinding offerrous and non-ferrous metals, and a cement production in the world. A significant shortcoming of these mills is high specific energy consumption on grinding. A material grinding process in ball drum mills is executed by grinding bodies that move in a transverse section of a mill drum. Besides, only 50% of grinding bodies grind a material, and the remaining 50% are dead zones- do not grind a material. An intensification of grinding media movement enables to improve an efficiency of the grinding process. The intensity of the grinding process is directly proportional to a power consumption value. Recently, ball drum mills with transverse longitudinal movement of grinding bodies showed a progress the grinding process intensification. Specific energy consumption for the grinding dropped down to 30%. Current methods of power consumption calculation of a mill drive do not allow determining the power consumption for ball drum mills with a cross-longitudinal motion of the grinding media. A new calculation method has been developed taking into account different designs of integrated devices and modes of the grinding media motion.

Key words: Ball drum mill · Grinding media · Material grinding · Grinding efficiency · Mode of grinding media motion · Power consumption · Calculation method

INTRODUCTION

Hundreds of billions tons of rocks are finely ground in many industries like mining, chemical, energy, building. Countries where those industries are developed the grinding process consumes up to25% of its energy resources [1].

The ball drum mills are traditionally used as a main grinding equipment, which has a large hourly production capacity (up to800 tons per hour) [2-5].

A significant is advantage of these mills is alow efficiency, which does not exceed 5%.

The mill design has not undergone major changes so far(German Patent, 1896).Overall size has been increasing, a shape and materials of a lining has been improving, various grinding circuits has been used, and a control system has been automated. However, all this has not led to a significant increase in the efficiency of the grinding process [5-7].

For the first time in world practice, Bogdanov (USSR Certificate #733727.1977) has proposed design of the ball drum ill with cross-longitudinal motion of the grinding media [8].

This design has significantly improved the efficiency of the grinding process. The specific energy consumption has decreased down to 30% [9].

According to experts, no fundamentally new technological methods of grinding will be created in the near future. Integrated activities only will be carried out forum proving the well-known technology, maintainability, grinding technique, cost efficiency [3-6].

Vertical and horizontal mills are gaining acceptance in recent years [3, 5, 6]. Since they contain the same grinding principle as in the ball drum mills, should not expect a great reduction of the specific consumption of energy for grinding.

Corresponding Author: Vasily Stepanovich Bogdanov, Belgorod State Technological University named after V.G Shukhov, 46 Kostukova str. Belgorod 308012 Russia.

Currently, best examples of ball drum mills in cement grinding indicate the specific energy consumption closer to those of vertical mills, and they cost up to 40%lower than the vertical ones.

Problem Statement: The theoretical models for calculating the power consumption of the grinding bodies motion of the mills based on a two-phase model of the ball movement.

In general, the power consumption is calculated by the formula:

$$N(A\lambda VSD^{0.5}) \tag{1}$$

where: A -constant of S. E.Andreev; S(Ψ,φ) – speed power factor.

All current theoretical studies are based on the solution of the formula (1), although, they are based on different hypotheses, finally, the authors clarify the form of the functions (Ψ,φ) -the main difference in this work.

The general conclusion of those studies is the following: they aim to clarify certain provisions of there cognized techniques based on the use of modeling and automated methods of calculation.

Thus, the power consumption calculation of the grinding media movement in a drum mill comes to the determination of S(Ψ,φ) function. Since a conventional mills load factor does not change during a grinding cycle, power remains unchanged. Although, professor D.K. Krukov showed that the function N(S) is apulsating function.

A degree of charge factor varies in magnitude from low to high during a grinding cycle in the mills with cross-longitudinal movement of the grinding media. Presumably, form of the function S (Ψ,φ) will change similar to the variation of φ(δ,β,ε).

Known methods of calculating power consumption of drum mills with vertical diaphragms cannot be used for calculating the power consumption of the mills with cross-longitudinal movement of the grinding media, because they do not reflect the actual work of the grinding bodies.

The following options of calculating power consumption for the grinding media displacement are discussed in this study based on the analysis of the mills with cross-longitudinal movement of the grinding media.

First, calculation of the power consumption of drum mills, equipped with one or several inclined intermediate diaphragms.

Second, determination of the power consumption required to move the grinding media in the mills, equipped with inclined rings.

Thirdly, calculation of the power consumption of mill sequipped with the lining of variable coefficient of engagement.

The character of cross-longitudinal motion the grinding media in mills equipped with different types of devices indicate that they have certain common patterns in the power transmission from a drive to grinding bodies. For example, an intermediate diaphragm or in cline dring can be considered as an inclined plane in a mill.

If the height of the inclined ring equal to the height of the grinding media layer, it can be assumed, obviously, that the in clined diaphragm affects the grinding media as equal as the inclined ring. Consequently, the power consumption calculation is identical.

If the height of the inclined ring less than the height of the grinding media layer, the ring moves that portion of the grinding media, which contacts the side surface of the ring. Presumably, in this case the power expended on moving the grinding media by the ring is less than the first one. The energy required to move the grinding media by the inclined ring is proportional to its height.

It is obvious, that the active zone of influence is necessary to be considered in the calculations precisely for the influence of the intermediate diaphragm restricted by a certain radius of that zone. Outside the zone of active influence, the energy consumption for the grinding media relocation can be estimated in the same way as in conventional drum mills, considering the work mode of grinding media, varying during the working cycle.

There fore, it is necessary to calculate the additional power, required to move the grinding media outside the radii of the active zones of influence of the intermediate diaphragm, and determine the total capacity primarily during calculating a power consumption of drum with cross-longitudinal movement of the grinding media.

Mill Drive Capacity: Capacity of the mill drive with cross-longitudinal movement of the grinding media is:

$$N_{\text{ДВ}} = N_0 l \eta_1 \eta_2 \tag{2}$$

where: N_0- power to the output shaft of the gearbox; η_1, η_2– efficiency of the mechanical transmission and the engine, respectively:

$$N_0 = N + N_{\text{П}} = N + N_X + N_{\text{ДП}} \tag{3}$$

where: N – power to the movement of grinding media; $N_{\text{П}}$- power to overcome the losses in the pin bearings; N_X- power to overcome friction in the bearings without loading the drum; $N_{\text{ДП}}$ - extra power to overcome friction in the bearings, considering the load of the grinding media.

Power to the Friction Forces in the Pin Bearings: Power loss at idle operation to overcome friction in the pin bearings is:

$$N_X = M_r\,\omega = N_X = f_r\,G_{\text{ВЧ}}\,r_{\text{Ц}}\omega = 2\pi f_r \Psi r_{\text{Ц}} G_{\text{ВЧ}} \tag{4}$$

where: M_r - moment of friction in the bearings; f_r– coefficient of sliding friction(in the case of rolling bearings- the coefficient of rolling friction); $G_{\text{ВЧ}}$ - weight of the rotating parts (drum, lining, intermediate diaphragms, output grate); r_u - the radius of the journal(in case of rolling bearings-the radius of the bearing ring on which the balls roll).

Power to Overcome the Friction in the Bearings: Considering the mass of the grinding media, the power is:

$$N_{\text{П}} = (1 + c_1)N_X \tag{5}$$

For mills with vertical diaphragm the coefficient in the formula (5) is equal to, depending on the radius of the mill drum it varies $0.25<x_1<0.60$ (0.45m<R<1.35m). When R>2м, ☻ comes to $c_1=1.0$.

Mills with cross-longitudinal movement of the grinding media, due to changes in the level and the center of mass of the grinding media ☻ during the working cycle varies depending on not only ξ, φ, Ψ, but also on the β, studies have shown.

The coefficient ☻ for laboratory mills with R<0.5 m is recommended to take $c_1=1.15$, experiments have shown.

The value of ☻ does not exceed 0.1 for industrial mills, therefore, ☻ is very small, and lies within the tolerances of $N_{\text{П}}$; so the coefficient c_1 for mills R> 1mcomes to 1 by analogy.

Consequently:

$$N_{\text{П}} = N_X(2 + c_1)\,2\pi f_r \Psi r_{\text{Ц}} G_{\text{ВЧ}}(2 + c_1) \tag{6}$$

Power required to cross-longitudinal movement of the grinding media equals:

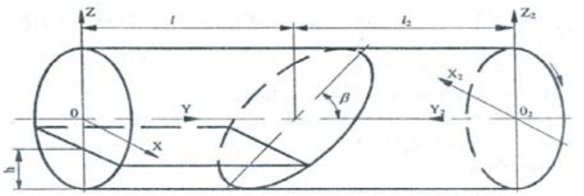

Fig. 1: The volume occupied by the grinding media in a single mill chamber at ξ=☻

$$N = N_1 + N_2 + N_3 + N_4 \tag{7}$$

where: N_1 - power to the movement of the grinding bodies in the zone of the radius of the active influence of the inclineddiaphragm;N_2– power to a waterfall work mode of the grinding media; N_3 –power to the cascade work mode of the grinding media; N_4 –power to overcome friction of the grinding media and the lining.

Additional Power to the Longitudinal Movement of the Grinding Media: A power to move the grinding bodies by an inclined plane, comprises the sum of power N_B-the vertical movement of the center of the grinding media mass, and power N_T- to over come friction in the longitudinal motion of grinding media.

$$N_1 = N_B + N_T \tag{8}$$

To calculate N_1 the coordinates of the center of the grinding media mass are defined below.

According to the design scheme (Fig. 1), the coordinates of the center of the grinding media mass of one grinding chamber:

$$x_C = \frac{1}{v_f}\iiint_{(v)} x\,xyz$$
$$y_C = \frac{1}{v}\iiint_{(v)} y\,xyz \tag{9}$$
$$z_r = \frac{1}{v}\iiint_{(v)} z\,xyz$$

The integration of the system (9) is over the volume occupied by the grinding media (Fig. 1), which is bounded by the surfaces:

$$\begin{cases} x\sin\xi - (y - j)tg\beta + z\cos\xi = 0; \\ x^2 + z^2 = R^2; \\ z = -(R - h); \\ y = 0 \end{cases} \tag{10}$$

The grinding media level is determined by the equation:

$$0,5\pi - \arcsin x - x(1-x^2)^{0,5} = \pi\varphi + 2\cos\xi(1-x^2)^{0,5}/3\lambda tg\beta \tag{11}$$

The grinding body, outside the active zone of influence by inclined diaphragm, move as the mill with vertical diaphragm, and it does not lead to a power consumption increase.

Using equation (11), calculate the integrals (9) to the extent limited by the system (10).
After appropriate conversions:

$$L_z = \frac{0,25\pi\varphi\sin\xi}{tg\beta} + \sin\xi/6tg\beta(\frac{\cos\xi}{\lambda tg\beta} - B_X)\times(1-x^2)^{1,5}; \tag{12}$$

$$x_C = R^4 L_X / V; \tag{13}$$

$$L_Y = \frac{(1-4B^2)\pi\varphi}{8tg^2\beta} + [\cos\xi - B_X/4B\cos\xi(B - x\cos\xi)]\frac{(1-x^2)^{1,5}}{12tg^2\beta}; \tag{14}$$

$$y_C = R^4 L_y / N; \tag{15}$$

$$Lz = \frac{0,25\pi\varphi\cos\xi}{tg\beta} + [\cos\xi(\cos\xi - B_X) - 4B(B - x\cos\xi)]/16tg\beta; \tag{16}$$

$$z_C = R^4 L_Z / V \tag{17}$$

One example of calculating the coordinates of the center of the grinding media mass is shown in Fig. 2. The calculation is for the case where the active area of influence of inclined diaphragm extends the entire length of the chamber, i.e. [*lambda*]$_1$ = [*lambda*]$_p$

The center of the grinding media mass of the mill with a vertical diaphragm is at point A on the axis y_c/R. Longitudinal movement of the center of the grinding media mass in the same mill, equipped with an inclined diaphragm, reach maximum values at the angles of the rotation drum [*xi*] = 360°; 180°. In this example, the center of the grinding media mass at the mill 4x13.5 m moves along the axis of the drum at a distance of y_c = 1,58 *R* = 3,16м, or about the point A 1.58 m. When $[xi] = \frac{\pi}{2}$ coordinates y_c,z_c of the center of the grinding media missing the mill, equipped with inclined diaphragm, for y and z axes coincide with the coordinate of a point A, at the same time, the center of the grinding media mass is displaced along the x-axis for a maximum distance, equals to 0.6R or 1.2 m. In the angles area $[xi] = 1,5;\frac{\pi}{2}$ of the center of the grinding media mass is displaced along the x-axis to a distance1,2 Ri.e.2.4m.

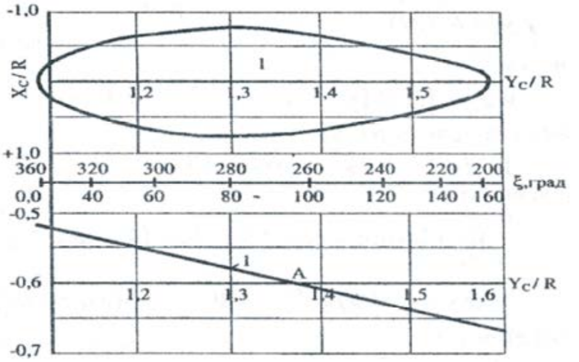

Fig. 2: Center of the grinding media mass inthe first chamber of the mill4x13.5 m

[*fi*] = 0,3;[*fi*] = 0,76; [*betta*] = 50°; [*lambda*]$_1$ = [*lambda*]$_p$ = 2,63

Therefore, the center of the grinding media mass in the mills and cross-longitudinal motion of the grinding media executes a complex motion per cycle along the y-axis the trajectory is a elongated ellipse, with the center in the center of the grinding media mass of the mill with a longitudinal movement of the grinding media, the major axis of it coincides with the longitudinal axis at the drum; relative to the plane ZOY is an inclined line (whose inclination angle equals to the angle of repose of the grinding media), passing through the center of the grinding media mass of the mill cross-longitudinal motion of the media. The movement character of coordinates of the center of the grinding media massing mills with cross-longitudinal movement of the grinding media, during a working cycle relative to all coordinate axes, indicating more in tense movement of the grinding bodies in comparison with conventional drum mills. Finally, suggestion can be made as the greater mobility the grinding media have the greater job then the grinding bodies do. Based on abovementioned, we can make a general conclusion that increasing the angle of repose of the grinding media the loading zone of active influence of inclined diaphragm decreases, consequently longitudinal movement of the center of the grinding media mass reduces, as well as further power consumption.

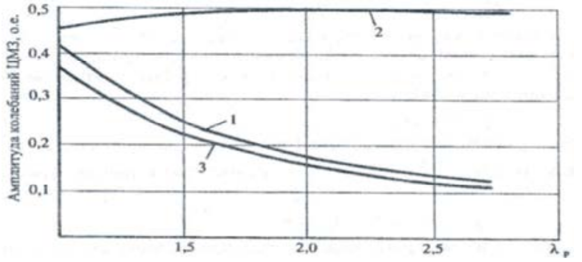

Fig. 3: Dependenceof the center of the grinding media mass movement on the size of the active zone of influence of the inclined diaphragm: 1- along the axis OX; and 2-along the axis OX; 3 - along the axis OZ.

However, as follows from Fig. 3., decrease of [*lambda*]$_p$ (at the appropriate angle of repose of the grinding media [x_i]) causes an increase in the amplitude of the oscillation of the center of the grinding media mass along the axis OX and OZ, at the same time, the amplitude of the oscillations a long the axis OY remains almost unchanged. For example, the amplitude of oscillation along the axis OZ increases from 0.11 to 0.37 R when [*lambda*]$_p$ decreases from 2.5 to 1, i.e. 2.5 times, and along with OX 0.13 to0.42 R, i.e.3.3 times, the amplitude of longitudinal displacement a long the axis OY decreases, respectively, from 0.49 to0.46 R, i.e. slightly. It follows that the grinding media with the low angle of repose, even if greater [*betta*] and hence, lower [*lambda*]$_p$, exhibits high mobility in the are a of the inclined diaphragm work at a constant amplitude along the axis OY, and amplitude along the axis OX, OZ increases three times.

This, the increase in drive power consumption for moving the grinding media for constant mass of grinding media and the frequency of rotation of the drum provides a proportional increase in performance in the mills with the cross-longitudinal motion of the grinding media. Other things being equal, large amplitude of the center of the grinding media masses change area chieved at lower values of the angles of repose of the grinding media. Consequently, the mills with cross-longitudinal motion of the grinding media should have the smallest possible angle of repose of the grinding media.

The work required to lift the center of the grinding media mass equals:

$$A_B = \Delta z_C G_? = A_B = g\gamma\Delta z_C V \quad (18)$$

where: G_3- weight of the grinding media, transported by the inclined diaphragm; Δz_c*-change* of the center of the grinding media mass coordinate along the axis OZ.

The additional power consumes for lifting the center of the grinding media mass, because of the forces, acting on the grinding media from the side of the inclined diaphragm (shortening the chamber in length), which equals:

$$N_B = dA_B / dt = N_B = g\gamma N z_C = g\gamma R^4 L \quad (19)$$

As show nabove, during the cycle center of the grinding media mass moves not only relative to the vertical axis OZ, but also, to a greater extent, along the axis OY. In this case, additional work expended on overcoming the friction of the grinding media is:

$$A_{TP} = -F_{TP}s = A_{TP} = f_C g\gamma s V \quad (20)$$

where: F_{TP}- friction force; s –center of the grinding media mass displacement along the axis OY.

The power corresponding to this work:

$$N_T = F_C g\gamma V s \quad (21)$$

Considering that V = const, a ☻ can be represented as:

$$N_T = f_C g\gamma R^4 [L_X^2 + L_Y^2]^{0,5} \quad (22)$$

This, additional power consumption expended on the longitudinal motion of the grinding media by an inclined surface in certain mill chamber, for example, in the first is:

$$N_{ДП1,2} = g\gamma_1 R_1^4 (v_{1Z} + f_1 (v_{1X}^2 + v_{1Y}^2)^{0,5}) \quad (23)$$

In the second mill chamber, the grinding media in the zone of active influence of the inclined diaphragm moves as well as in the first, but the movement process is shifted in phase by☻.

Power required moving the grinding media by the inclined diaphragm, in the second mill chamber:

$$N_{ДП1,2} = g\gamma_2 R_2^4 (v_{1Z} + f_1 (v_{1X}^2 + v_{1Y}^2)^{0,5}) \quad (24)$$

where: R$_2$☻- parameters, characterizing the dimensions and the grinding media in the second chamber.

The total power consumed for cross-longitudinal motion of the grinding media in both chambers is:

$$N_{ДП} = N_{ДП1} + N_{ДП2} \quad (25)$$

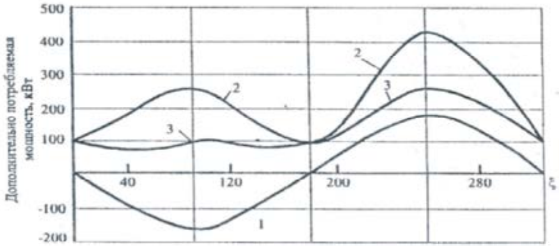

Fig. 4: Calculated dependence of ☻ (ξ) 1 – $N_{ДПВ}(\xi)$

Power required to cross-longitudinal motion of the grinding media, having mills with several intermediate diaphragms, equals:

$$N_{ДП} = \Sigma_{i=1}^{n}\Sigma_{j=2}N_{ij} \tag{26}$$

where: n - number of inclined intermediate diaphragms in stalled in the mill drum.

Further Discussion of the Results of Additional Power Consumption Calculation: The calculation of $N_{ДП}$ reduces to as follows.

According to structural and technological characteristics of the mill- R,l_1, [*betta*],[*fi*],[*psi*],[*epsilon*], *f* for different angles [*xi*] of the relative radius of the confluence zone of the in clined diaphragm, the parameters x, v_x, v_y, v_z are defined(by the corresponding equations); and finally, the additional power consumption of $N_{ДП}$ as a function of [*xi*], $N_{ДП}(\xi)$ is calculated by the formula(25).Figure 4shows the typical dependence of $N_T(\xi)$, $N_B(\xi)$ and $N_1(\xi)$ as an example of one grinding chamber 4x13.5 m

Graphic functions $N_T(\xi)$, $N_B(\xi)$ are sinusoid a land have equal phase- π. Where the function $N_T(\xi)$ has larger amplitude, i.e. in a cross-longitudinal motion of the grinding media by the intermediate diaphragm most of the energy is consumed to over come the frictional forces in the longitudinal movement of the grinding bodies than to lift the center of the grinding bodies mass.

In the angle sector of 0°<[*xi*]<180° function $N_B(\xi)$ is even negative. The physical nature of the phenomenon is explained by the fact that the grinding bodies accumulate energy, which expended on longitudinal movement of the grinding bodies (extension of the chamber length), when the chamber length is decreasing and the center of the grinding media mass is lifting up.

The maximum and minimum values of N_T, $N_B(\xi)$ functions correspond to the angles of rotation of the drum [*xi*] = $\pi/2$;[*xi*] = 0;2π;π..

The total additional capacity of the angle of rotation phase of the drum 0<[*xi*]<2π is almost unchanged , it is in this ranget hat the length of the chamber increases, and the stored potential energy, when lifting the center of the grinding media mass, is expended on the longitudinal movement of the grinding media.

In this case, a maximum of 250 kW of energy required on overcoming the friction forces, but the mill consumes only about100 kW.

Additional150kWprovidedby that the gravity lowers the center of the grinding media mass is due to the increased length of the chamber, and the stored potential energy is used toover come friction forces, i.e. for the longitudinal movement of the grinding bodies.

In phase π<[*xi*]<2$\underline{\pi}$, when the length of the grinding chamber decreases N_T, $N_B(\xi)$ at [*xi*] = 1,5π reach maximum values: N_T = 250kW, N_B = 170kW, and the total additional power is $N_{ДП}$= 420kW.The maximum power consumption, which is known from the theory of drum mills, corresponds to the highest efficiency of the grinding process.

In the phase of π < [*xi*] < 2π, when the length of the chamber decreasing, the maximum energy expended for the grinding media movement, hence the grinding media is committing he greatest work of the grinding.

This is confirmed by the theoretical findings earlier: reducing the length of the chamber for a constant mass of grinding media leads to an increase in the degree of charge(relative charge factor);mode of grinding media work is avalanche waterfall; a maximum angle of separation; the drop height and the energy at the point of maximum in pact, because of the time the grinding media fall drum manages to turn at an angle $\pi/2$ and level of charge in the chamber is reduced to the minimum possible.

Presumably, the amount of energy, expended to lift the center of the grinding media mass, characterizes the portion of an impact grinding, but to overcome the forces of friction –an abrasive grinding. Based on this, additional 40% of power consumption in this example consumes for impact crushing i.e. an abrasion grinding prevails when the grinding bodies present cross-longitudinal motion.

This, about 100 kW of power consumed in addition (in this example)in the rotation phase of the drum 0 < [*xi*] < π for the longitudinal movement of the grinding media, and up to430kW- in π < [*xi*] < 2π phase. Power, consumed by the cross-displacement of the grinding media, calculated according to known methods in the area of active influence of intermediate diaphragms ([*lambda*]$_p$ = 2,63 comes up to 420kW.The total power consumed for movement transverse to the longitudinal loading in phase $0 < [xi] < \pi$ is equal to about 520kW and in Phase $\pi < [xi] < 2\pi$ double sand reaches at 850kW.

These theoretical results provide a basis for developing innovative designs of integrated devices and grinding machines in general. As it is, the method of calculating the power consumption of the longitudinal movement of the grinding media was developed for the first time, thus, it is suitable for all designs of integrated devices.

CONCLUSION

Analysis of state of the art direction sand technology of grinding of various materials confirms the feasibility of improving the design of ball drum mills. Using well-known methods for calculating power consumption of ball mill drives with transverse motion of the grinding media is not possible, as in the ball mill design suggested by the authors founded another nature of the movement of the grinding media, namely, the cross-longitudinal movement.

The proposed calculation method the power consumed by the ball mill drive with al cross-longitudinal motion of the grinding media is tested on different standard sizes of mills, and shows high accuracy. Differences between design values and measured data do not exceed 5%.

The derived formulas allow considering various integrated devices in the mill, which provide cross-longitudinal motion of the material.

Proposed in the first time method of power consumption calculation of the ball mill drive with cross-longitudinal motion of the grinding media allows calculating the power of the drive considering the design of integrated devices in the mill, the intensity of the grinding media motion, to determine the rational rotating speed of the mill drum, which provide the maximum power consumption, corresponding to the highest efficiency of the grinding process.

REFERENCES

1. Johim Harder, 2008. OneStone Consulting Group GmbH, Cement industry in 2010, Cement, Lime, Gypsum, Jounal, 2: 39-45.
2. Perov, V.A., E.E. Andreev and L.F. Bilenko, 1990. Crushing, grinding and sifting minerals. – M.:Nedra, pp: 301 (in Russian)
3. Duda, W.H., 1978. Cement Data Book, Bauverlad.Wiesbaden, 1978. Nordberg grinding mills. MaterialyfirmyNorberg-Division of Rex ChainbeltJne., Milwaukee, 1971.
4. Krufger, W., 1984. Eualnation of grushing and grinding systems for three different types of raw material. The Neu cement und technologieconferenzieanateim, Californij, 21-24 maw, 1984.-New York, pp: 1-21.
5. Bogdanov, V.S., R.R. Sharapov and M. Fadin Yu, 2012. Basis of calculating the building materials industry machines and equipment: manual - Stary Oskol; publishing house LLC "TNT", pp: 688 (in Russian)
6. Morozov, E.F. and A. Muyzemek Yu., 1971. Energy consumption in a ball mill at cascade mode. – Proceedings of higher education institutions “Mining Journal, 8: 157-161 (in Russian)
7. Shinkorenko, S.F., 1973. Of power consumed by a mill for rotating the ball load. – In the book.: Ferrous metal ores beneficiation, M.: Nedra,1973, pp: 95-102. (in Russian)
8. Bogdanov, V.S., 1985. The energy-exchanging appliances for ball drum mills. – “Glass and ceramics, 1985, #6, pp: 19-21 (in Russian)
9. Maschinen fur die Aufbereitung Zerkleinerungsmachinen Rohrmuhle KRUPP. Aufbereitungs Technik, 1967, 7: 382.
10. Morozov, E.F., 1971. The useful capacity of a ball mill at cascade mode. Mining Journal, 12: 52-56 (in Russian)