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Definition of Rational Conditions of Materials Grinding in Energy-Saving Milling Complex*

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Abstract: Current issues of energy saving in cement production, using technological milling complex, which includes a press roller crusher and ball mill, discussed in the article. Optimized milling conditions of previously ground material through the installation of energy-exchange blade devices (EBD) in amill drum have been proposed. It was found that the level of charge by grinding media in the first chamber periodically varies according to the rotation angle of the mill drum equipped with EBD. There is a "scooping" of the grinding media with a grinding material in the zone of active influence of EBD along, lifting them to a height and enforcing them a cross-longitudinal movement. All that is different from being created in the ball mills without EBD. The additional work is performed, which consumes engine power. Method of calculating anadditional power consumption of the mill drive equipped with EBD was proposed; additional power expended to create cross-longitudinal motion of the grinding mediain the first and second chambers initsareas of activein fluence of EBD. The comparative analysis of the results obtainedby experiment and calculation son the proposed equationss howed high convergenceresults. The analytical dependencies maybe of interest for both Russian and foreign organizations operating in the design and manufacture of cement equipment, as well as for cement manufacturers.

Key words: Energy intensity · Complex of grinding · Pressroller grinder · Ball mill · Method of calculation · Additional power consumption · Energy-exchange blade devices

INTRODUCTION

Among the most energy-intensive processes are the processes of crushing andmillin graw materials,which consumes about10% of the world's electricity in the production of binders, different mixes and products. At the same time, power consumption in creases significantly within creasing a product fineness.

It is known, that power consumption for crushing is 10-21J/g and 360-3600 J/g for fine and super fine grinding [1].

There fore, studies a imed at improving the grinding technology and equipment to reduce energy intensity of the process are relevant.

In cement production with the annual volume, which is continuously increasing in the world and currently more than 2.5 billion tons, the processes of millin graw materials and cement,under taken mainlyin ball mills, expend from 40 to70% of all electricity in the process [2].

Scholars and practitioner sin our country and abroad are involved in developing new machines and improving the efficiency of existing milling equipment [4-8].

Energy-saving technology for the grinding of cement was developed by them as a complex consisting of two units of a press roller grinder and a ball mill (PRG-BM) [9-11].

RESULT AND DISCUSSION

The studies found that the milled materialin PR Gafter the pressure treatment between the rolls is significantly different from the original. Material presents in the form of pressed plates and its

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Fig. 1: Feed material(clinker)

Fig. 2: Clinkergroundin the PRG

particles have microdefect structure that requires special conditions for their milling in the ball mills (Fig. 1, 2).

The material, that was pre-ground in PRG, is subject to momentary force impact in the first mill chamber for disagglomeration compacted material by abrasion-grinding effect of the grinding media in the second mill chamber for its final milling, study revealed. Such conditions can be obtained by grinding the materials in a ball mill, equipped with energy-exchange blade devices (EBD), double acting blade (DAB) and elliptical blade segment (EBS).

To determine the operating modesof grinding mediafor different schemes of EBD setup, studies were carried out on the model of a ball mill with a transparent body of ⌀0,1×0, 5msize (Fig. 3a-d), at a smallinnovative company"Center ofenergy-saving technologies and systems" based on innovative business incubator Belgorod State Technological University named after V.G. Shoukhov within the states upport innovative entrepreneur ship of young scientists in Russian universities [12].

The studies found, that the nature of the dynamic impact of the grinding bodies in the BMis under substantial influence of the relative position EBD,both longitudinally and in cross section of the mill drum.

Thus, when EBD is set at the dischargeend of the mill drum and inclined to the bottom of it, or its major axis coincides with the major axis DAB (Fig.3a) the simultaneous effectto grinding media appears, with a 360° spacing. This leads to concentration of the grinding bodies in the middle of the second chamber, which negatively affect the efficiency of a grinding process.

Turning the EBD relatively to the DAB at 180° (displacement of the major axes at the 180°angle) leads to alternate impact of the EBD on the grinding media, leading to their greater mobility, displacement and concentration, here at the DAB and ther eat the EBD (Fig. 3b). Such EBD setup schemes hould facilitate intensity of the process of grinding the pre-ground material in the second chamber of the mill.

However, setting the EBD,tilted to the bottom of the dischargeend, results in the capture of the cylpeps media by EBD and lifting it to greater heights, which leads to a partial water fall workmode, which will reduce its effectiveness in the second chamber.

Changing the tilt angle of EBD to the opposite, setting it at an angle from the dischargeend (Fig.3), results in the "waterfall effect" vanishing in the second mill chamber. Since, such a location of EBD does not lift the grinding media, but only increases its impact in the longitudinal direction; it positively affects the grinding material.

Turning the EBD relatively to the DAB at the angle other than 180° (e.g.90 or 270) leads to partial concentration of the grinding mediain the chamber center (Fig. 3 g). It comes from the over lap of the pulses from the impact of DAB and EBD, which also negatively affect the efficiency of the grinding process.

Installation of double action blades will provide as hock-abrading effect of the grinding media to the grinding material in the first mill chamber.Controlling the pulse range of DAB, besides the angle of in clination, ensures the presence of horizontal sections of the diaphragm.

Thus, the research of the nature of the grinding media motion in the BM equipped with EBD showed that the work mode of the grinding media depends on the setup schemeand arrangement of DAB and EBD. Rational EBD setup scheme in a mill drum forgrin dingpre-ground materials in PRG is a diagram (Fig. 3c), where the shock-abrasive effec tof the grinding media in the first mill chamber and the crushing-abrading effect in the second.

Installation of energy-exchange blade devicesin the form of a double-acting blade (DAB) and blade elliptical segment (BES) in the ball mill drum allows intensifying the grinding media studies have shown. However, the level of the grinding media in the first chamber varies periodically according to arotation angle of the mill drum; and in the active zone of EBD influence "scooping" of the grinding

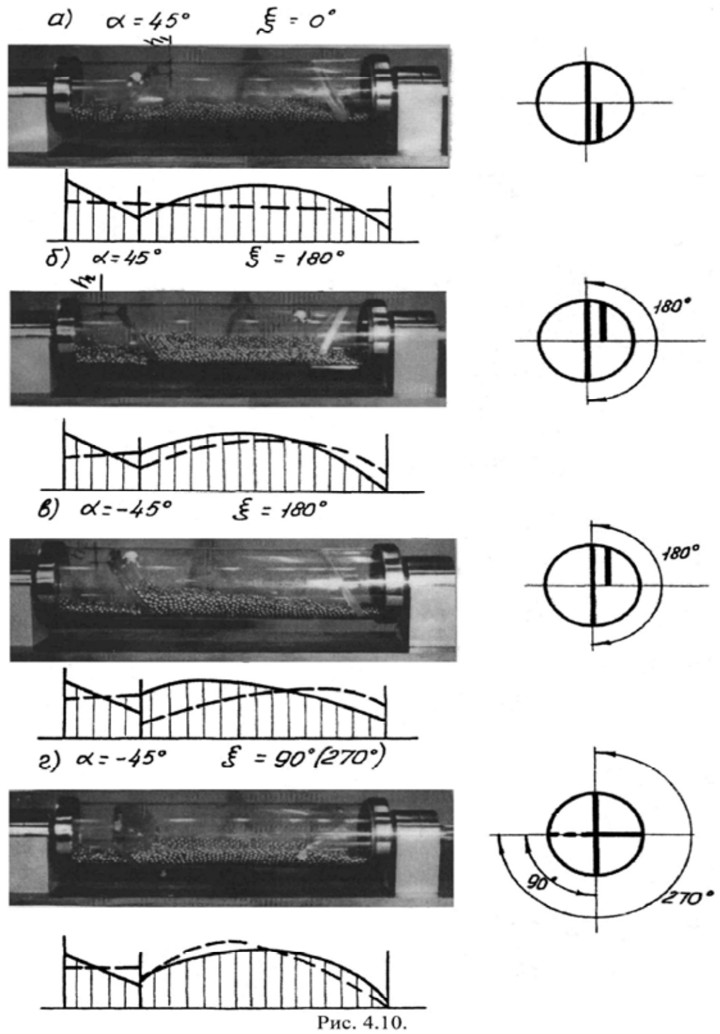

Fig. 3: Setup diagrams EBD in BM and diagrams of the movement of grinding media

media with grinding material occurs, lifting them to a height and giving them cross-longitudinal movement, unlike produced in mills without EBD (Fig. 4). At the same time, take sadditional work, which increases the power consumption. Lack of scientific methodology for calculating the amount of power for mills equipped with EBD in hibits their adoption by the industry.

Additional power consumption of the mill connected (compared with wind mills with vertical partitions) with reposition of the center of the grinding media massalong the axis of the mill drum, by influencing the grinding media in the long itudinal direction of DAB and EBD.

Power N for a certain period of time T is calculated by the for mula:

$$N = \frac{A}{T}, \quad (1)$$

where, A -the work donefor the sameamount of time T.

Thetime taken for onerevolution of the milldrum,over theperiod of time T, when the millperformsnrevolutions perminute, allowsone revolutionto occurin a timeequal to:

$$T = \frac{1}{n};\ \text{min} \quad (2)$$

or

$$T = \frac{60}{n};\ \text{sec} \quad (3)$$

because

$$n = \psi n_{\text{èð}} \quad (4)$$

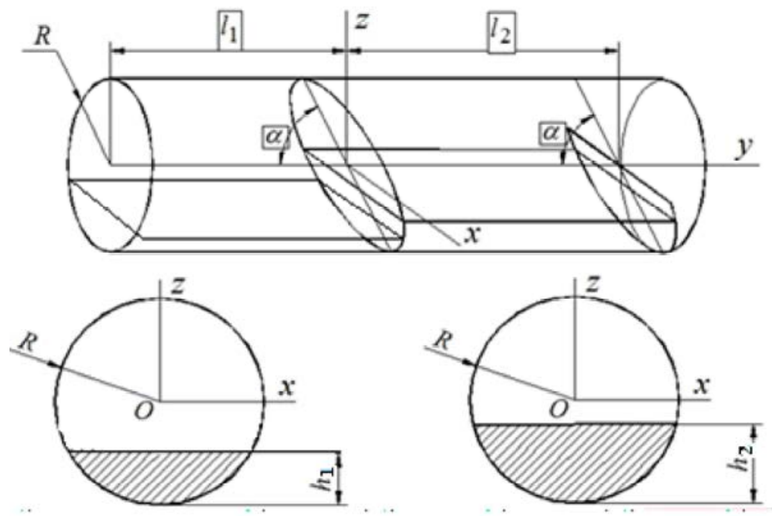

Fig. 4: Setup scheme of EBD in the ball mill drum

where, Ψ [Psi] – relativerotation speed; $n_{\kappa p}$ – a criticalrotation speed.

Since,

$$n_{\kappa p} = \frac{30}{\pi}\sqrt{\frac{g}{R}} \quad (5)$$

where, g = 9,81m/s^2-acceleration of gravity; R-the radius of themill drum; formula (3) can be written as:

$$T = \frac{2\pi\sqrt{R}}{\psi\sqrt{g}}; \text{ sec} \quad (6)$$

Durin gone revolution of the milldrum, the center of the grinding media massin each chamber will move from one extreme position to the other and back again.

For the first chamber relocation of the center of the grinding media mass per revolution of the mill drumis determined by the formula:

$$S_1 = 2\left|y_c - y'_c\right| \quad (7)$$

According to [6], y_c and y'_c are calculated by the formulas, respectively:

$$\tilde{y}_c\tilde{V}_1 = -\frac{\lambda_1^2}{2}\left(\chi_1\sqrt{1-\chi_1^2} + \arcsin\chi_1 - \frac{\pi}{2}\right) - \frac{2\lambda_1 \text{ctg}\alpha}{3}\left(1-\chi_1^2\right)^{\frac{3}{2}} + \\ + \frac{\text{ctg}^2\alpha}{8}\left(\chi_1(1-2\chi_1^2)\sqrt{1-\chi_1^2} - \arcsin\chi_1 + \frac{\pi}{2}\right).$$

$$\tilde{y}'_c\tilde{V}''_1 = -\frac{\lambda_1^2}{2}\left(\chi'_1\sqrt{1-\chi_1'^2} + \arcsin\chi'_1 - \frac{\pi}{2}\right) + \frac{2\lambda_1 \text{ctg}\alpha}{3}\left(1-\chi_1'^2\right)^{\frac{3}{2}} + \\ + \frac{\text{ctg}^2\alpha}{8}\left(\chi'_1(1-2\chi_1'^2)\sqrt{1-\chi_1'^2} - \arcsin\chi'_1 + \frac{\pi}{2}\right).$$

The center of the grinding media mass relocation per one drum revolution in the second mill chamber is determined by the formula:

$$S_2 = 2\left|y_{c2} - y'_{c2}\right| \quad (8)$$

The calculation of y_{c2} and y'_{c2}, according to (4) by the formula:

$$\tilde{y}_{c2}\tilde{V}_2' = \frac{\text{ctg}^2\alpha}{8}\left(\chi_2\left(2\chi_2^2 - 1\right)\sqrt{1-\chi_2^2} + \arcsin\chi_2 - \frac{\pi}{2}\right) - \\ -\frac{\lambda_2^2}{2}\left(\chi_2\sqrt{1-\chi_2^2} + \arcsin\chi_2 - \frac{\pi}{2}\right).$$

$$\tilde{y}'_{c2}\,\tilde{V}_2'' = \frac{\lambda_2^2}{2}\left(\frac{\pi}{2} - \arcsin\chi_2' - \chi_2'\sqrt{1-\chi_2'^2}\right) + \frac{2l_2\text{ctg}\alpha}{3}\sqrt{\left(1-\chi_2'^2\right)^3}.$$

Because the force of friction does the work, then:

$$A = \left|F_{\text{тр}}S\right| = F_{\text{тр}1}S_1 + F_{\text{тр}2}S_2 \quad (9)$$

In turn,

$$F_{\text{òð}1} = f\,G_1 = f\,M_1 g = f\,g\gamma V_{1\text{çàãð}} = f\,g\,\gamma\,\varphi_1 V_1 \quad (10)$$

where, f – coefficient of sliding frictionof the grinding media with the mill drum body; G_1 – load weight of the grinding media in the first chamber; M_1 – mass of the grinding mediain the first chamber; γ [gamma] – volume weight of the grinding media; $V_{1\text{загр}}$– volume of the grinding media in the first chamber; φ_1[fi] – coefficient of charge of the first chamber by the grinding bodies; V_1 – volume of the first chamber.

A similar formula holds for a second camera:

$$F_{\text{тр}2} = f\,G_2 = f\,M_2 g = f\,g\gamma V_{2\text{загр}} = f\,g\,\gamma\,\varphi_2 V_2 \quad (11)$$

Comparative results, obtained by calculation and experiment for the following values of in put parameters, are following: radius of the mill drum, R= 0.5 m; length of the first chamber, l1=0.65 m; degree of charge of the first chamber, □1=0.18; length of the second chamber, l2=1.3 m; degree of charge of the second chamber, □2=0.3;coefficient of sliding friction, *f*0.4;volume weight of the grinding media γ= 4550 kg/m3; angle of DAB and EBD to the axis of the drum mill, α= 60°; relative rotation frequency of the drum mill (corresponding) Ψ= 0.76.

The diver gence between experimentally determined and calculated values do no texceed 10%, results showed. At the indicated values of the input parameters, the additional power consumption, obtained by calculation was 62.2 W for the first camera, 441.0 W for the second camera for and 503.2 W in general for the mill; the experimentally obtained was 545.0 W.

The analysis of the plots of (Fig.5-8), allowed study of the influence of the first chamber length (lengt hof the second chamber, was such that the sum of chambers length sequaled tot he length of the mill- 1.95 m), tilt angle of EBD and degree of charge factors of the first and second chambers, on the additional power consumption.

The following designation sare indicated in the graphs: *N*1 and *N*2 – additional power consumption by relocation the grinding mediain the first and second chambers, respectively; N^1 – designed to taladditional power consumption; and N^3- total power consumption measured experimentally.

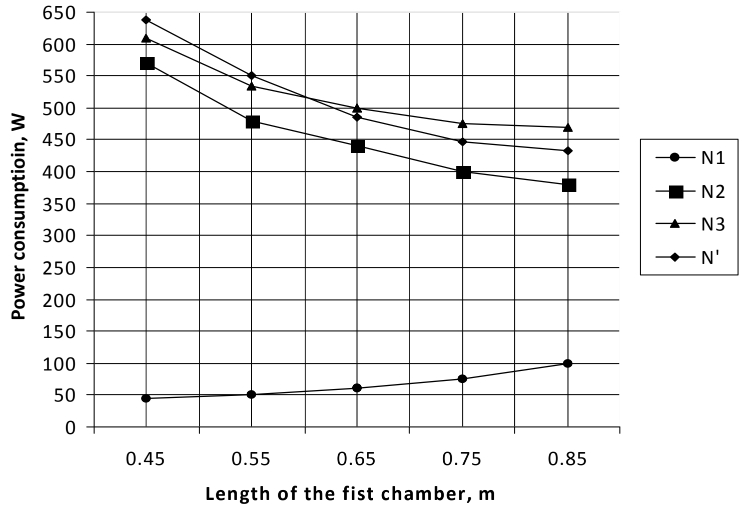

Fig. 5: Dependence between power consumption and length of the first chamber

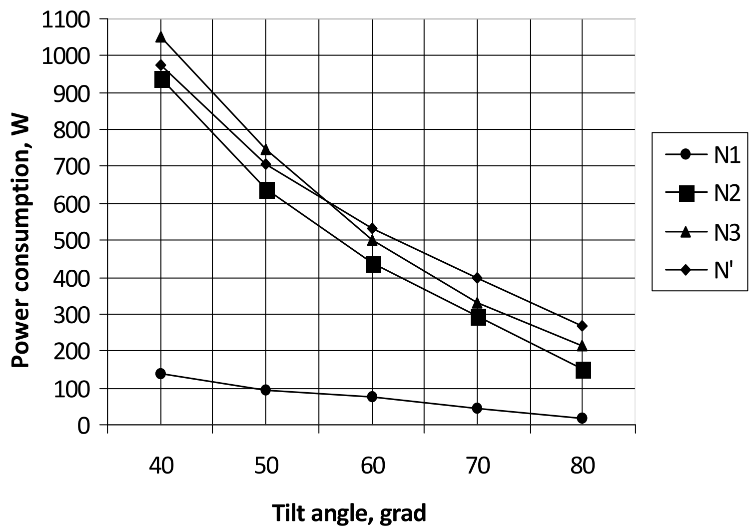

Fig. 6: Dependence between additional power consumption and angle of DAB and EBD to the axis of the mill drum

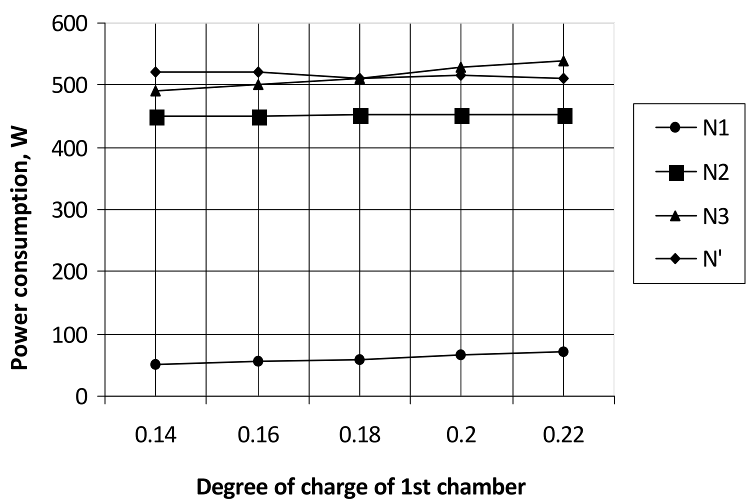

Fig. 7: Dependence between additional power consumption and degree of charge of the first chamber

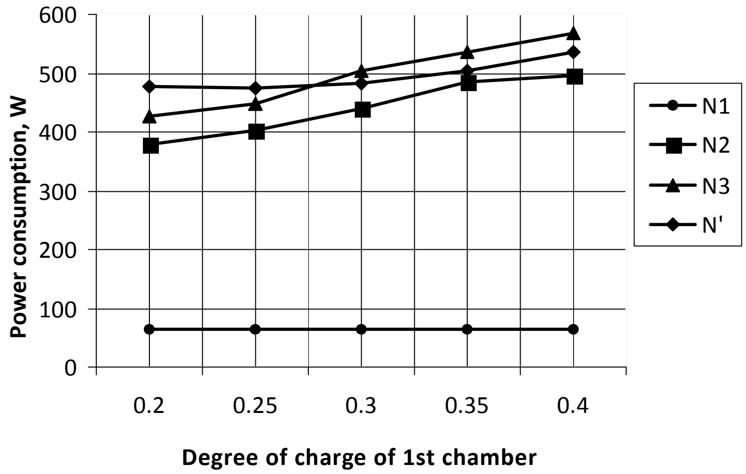

Fig. 8: Dependence between additional power consumption and degree of charge of the second chamber

Installation of energy-exchange device in the mill drum allows intensifying the work of grinding media, as indicated by the value of an additional power consumption of the mill drive, as can be seen from the plots (Fig. 5-8). Changing the length of the first chamber, in the direction of increasing it, results in a reduction of the total charge of the grinding bodies in the mill drum, which simultaneously leads to a reduction of power consumption by the mill drive and grinding quality deterioration (Fig. 5). Optional length of the first chamber for pre-grinding of a clinker of deformed structure is 0.65m, which is 1/3 of the totall ength of the ball drum mill.

The graphic dependence analysis (Fig. 6) showed, that changing the tilting angle of energy-exchanging blade devices to the axis of the mill drum, from 40° to80°,leads to afurther reduction in power consumption. It happens because the zone of influence of DAB decreases and in the second chamber, the zone of influence of BES on the grinding media, which leads to further reduction in power consumption. Increasing the degree of charge by the milling bodies in the first mill chamber from 0.14to 0.22 and the second-from 2.2 to 0.4 (Fig. 7and 8), leads to an increase in the total weight of the grinding bodies in the mill drum, that proportionally affects the growth of the additional power consumption of the machine.

CONCLUSION

The comparative analysis of plots (Figure5-8), based on the data obtained experimentally and by calculations, shows that the divergence between the experimentally determined and calculated values do no texceed 10%.

Thus, the installation of the energy-exchange devices in the mill drum allows intensifying the work of grinding media. This is indicated by the value of the additional power consumption of the mill drive.

Analytically obtained equations (10) and (11) allow us to calculate the additional power consumption of the mill, equipped with EBD and with sufficient accuracy, to show the real grinding process.

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REFERENCES

1. Bashkircev, A.A., 1986. Analysis of the efficiency of machines for fine grinding of building materials / A.A. Bashkircev // sb. nauch. tr. MADI.- 1986 (in Russian)
2. Bogdanov, V.S., 2008. Optimization of the process of grinding of cement / V.S. Bogdanov, R.R. Sharapov, Ju.M. Fadin // Mezhdunar. kongress proizvoditelej cementa 9-12 oktjabrja 2008g. Belgorod Shuhov V.G. State Technological University, Belgorod: sb. dokl. – M: Evropejskij tehnich. in-t, 2008. – s. 20-39 (in Russian)

3. Romanovich, A.A., 2011. Energy saving in production of building products // Vestnik Belgorod Shuhov V.G. State Technological University, 3: 69-7 (in Russian)
4. Cottrev, A., 1952. The oretical aspects of fracture N.Y.S.L / A Cottrev, pp: 202.
5. Dias.S/Influence of druinq on concrete Sorptivitq / S. Dias// Cement and Concrete Research. 09: 102-126.
6. Griffits, A., 1920. The phenomena of Rupture und Plou in solids / A. Griffits 221(587): 163-198.
7. Griffits, A., 1920. The phenomena of Rupture und Rlou in solids / A. Griffits, 221(587): 176-185.
8. Jones, M.R., 2003. Estimation of the filter content required to minimize voids ratio in conerete /M.R. Jones// Cement and Concrete Research, pp: 02.
9. Bogdanov, V.S., V.P. Voronov and F.P. Potapov, 2011. The calculation of the value of work is spent on the destruction of the material in cascade mode ball mill operation // Vestnik Belgorod Shuhov V.G. State Technological University. 1: 61-64. (in Russian)
10. Gridchin, A.M., 2002. Asphalt using anisotropic raw materials // Building materials, the equipment, technologies of the XXI century, 10: 5-7 (inRussian)
11. Romanovich, A.A., 2013. Definition of the center of mass of the ball load the first chamber of the mill, equipped with paddle energy-exchanged devices: Scientific Vestnik of NSTU, 2(51): 166-171. (in Russian)
12. Romanovich, M., V. Yevtushenko, L. Romanovich and P. Ospischev, 2012. State support for innovative entrepreneurship of young scientists on the basis of Russian universities and Belgorod region // Vestnik Belgorod Shuhov V.G. State Technological University, 2: 117-120. (in Russian).