N E W S
OF THE NATIONAL ACADEMY OF SCIENCES OF THE REPUBLIC OF KAZAKHSTAN
SERIES CHEMISTRY AND TECHNOLOGY
ISSN 2224-5286
Volume 2, Number 428 (2018), 6 – 17

UDC 621.926

D.B Arinova[1], E.S Askarov[1], G.Popov[2]

[1]Kazakh National Research Technical University named after K.I Satpayev.
Department of Standardization, Certification and Engineering Technology, Almaty, Kazakhstan;
[2] Sofya Technical university, Sofya, Bulgaria.

INVESTIGATION AND DESIGN TESTING OF THE CENTRIFUGAL GYRATORY MILL OF A COULISSE TYPE

Abstract. Every year in the world it is milled billions of tons of mineral raw materials. The process of crushing demands a huge amount of energy. The mining enterprises generally use mills of spherical type, the history of use of such mills contains more than 200 years.

Now the situation has changed, the energy efficiency becomes the most important indicator of work of a mill as energy rises in price, the status of environmental problems was considerably raised, the content of minerals in ore decreases. The question of a to create of energy efficient mills becomes very relevant.

Centrifugal gyratory mills are intended for a grinding of various mineral raw materials. Mills of this kind known already for a long time have also shown quite good results in work, lowered consumption the electric power is one of the main advantages of these mills.

In this work, the design of a centrifugal gyratory mill on the basis of the rocker mechanism is investigated. The mill has a number of advantages over analogs: simplification of a design, high dynamic stability, expenses of energy are reduced twice, etc.

For the first time, practical tests of mills were carried out on the ground of Scientific research institute of mineral processing of the National center for processing of mineral resources of the Republic of Kazakhstan. The principle of work of a mill which consists in plainly - a parallel movement of cylindrical grinding cameras – pipes in the plane of their perpendicular axis, at which each point of the grinding camera moves on a circle with a radius r of the mechanism of a mill equal to length of a crank [4] is investigated. The centrifugal force of counterbalances, unbalanced dynamic force and the moments are calculated, the power analysis is carried out.

Results: From indicators of a research it is visible that the offered mills have an indicator of specific productivity of equal 140 kg/kW or 8 kW on production ton. The offered mills surpass spherical mills in this indicator twice. In this scheme, theoretical steadiness of the mechanism is received. There are essential constructive achievements: there is one crank shaft, there is no excess communication, application of cogwheels isn't required that has considerably simplified a design.

The mill differs in the low level of metal consumption. For comparison we will tell that the spherical mill with a productivity of 10 tons/hour weighs 30 tons, the weight of the offered mill with the same productivity will be at the level of 8-10 tons. The mill has the low level of complexity of a design. Simplification of a design of a mill and reduction of its metal consumption has allowed to reduce mill cost in comparison with spherical approximately by 3 times, in comparison with the existing centrifugal mills by 1.5 times. The mill has high maintainability.

Results of the presented work are perspective for introduction at the enterprises of the mining and concentrating industry of Kazakhstan and can be used in is mountain - concentrating plants.

Scientific novelty. The novelty of the received results consists in the creation and the research of designs of centrifugal - gyratory mill at which optimum process of a grinding, power consumption, metal consumption and productivity of the mill is provided.

Practical importance is on the basis of calculations and experimental data and also in determination of its rational design and technological data. It is revealed that in the process of the experimental-industrial period, the mill on the ground of the State scientific production association of industrial ecology Kazmekhanobr (Almaty), which is a part of the National center for complex processing of mineral raw materials of the Republic of Kazakhstan, differs in the low level of metal consumption, has the low level of complexity of a design, mill cost in comparison with spherical approximately by 3 times, in comparison with the existing centrifugal mills by 1.5 times thereby decreases. The mill has high maintainability. Tests of mills have shown their profitability in energy consumption that is the most important indicator. And also an indicator of specific productivity of 140 kg/kW or 8 kW on production ton (in the course of test different types of raw materials have been used).

Key words: centrifugal - gyratory mill, crushing of mineral resources, metal consumption, energy consumption, a design, productivity.

1. INTRODUCTION

Every year billions of tons of mineral raw materials are ground in the world;

600 million tons of ore undergo milling in Kazakhstan. One of the main engineering procedures of the mineral processing is the process of grinding. Grinding is carried out in mills that is meant to be a greatly power-consuming process.

It should be noted that for the last 100 years the structural engineers have not made any significant changes to the conceptual design of the mills. Ball mills are mainly employed in the ore mining industry, roller mills and disintegrators are used in the construction engineering.

Ball-type tumbling mills have got widespread use, the history of their usage goes back for more than 150 years. The grinding bodies in ball mills are spherical balls, the force of grinding is the force of gravity. The grinding process takes place in special barrels with mixing balls. Ball mills are slow, simple in design, durable, reliable, nevertheless, the grinding process is inefficient; most of the energy of falling balls is spent on impacts against each other, resulting in high power consumption. The ball mill consumes approximately 15 ... 20 kW of energy (the main fraction of grinding is less than 74 μm) for the grinding of 1 ton of ore.

In the ball mill, balls move chaotically at the fall colliding with each other, contact of balls occurs along the point; the contact area is very small. As a result, the energy of the ball interference basically falls on the other ball. A fairly small amount of energy is spent for grinding raw materials.

The ball mill consists of a gear reduction with several stages. Reductor increases the cost of the mill, requires high maintenance, protection from abrasive dust that is very much in the conditions of grinding mineral raw materials in the mines.

The main element of the ball mill is a cylindrical drum having a measurable diameter from 2.5 to 5 m and length of 5 to 15 m. The given overall and expensive part requires protection against abrasive wear, it is usually armour plate made of manganese steel or rubber coating. The presence of such armour also increases the cost of the mill [2].

In many countries with a developed mining industry, including Kazakhstan, grinding ore and other mineral resources is one of the primary energy consumers. Previously, little attention was drawn to this indicator as energy was cheap, and there was a lot. At present, the situation has changed, energy efficiency is becoming an important indicator of the mill operation as energy is rising in price, the status of environmental problems has significantly grown, energy needs to be saved and preserved.

It is necessary to develop and implement mills with low energy consumption.

2. METHODS AND RESULTS. CENTRIFUGAL GYRATORY MILLS – OPERATION PRINCIPLE

Centrifugal gyratory mills are designed for grinding various mineral raw materials. Mills of this type have been known for quite some time (since the beginning of the 70s of the last century), they showed good results in the work, one of the main advantages of these mills is a reduced consumption of electricity.

The operation principle of such mill resides in a plane-parallel movement of cylindrical grinding chambers – tubes in plane perpendicular to their axes, where each point of the grinding chamber moves along a circle with a radius equal to the length of the crank r of the mill mechanism.

The plane-parallel movement of the grinding chamber enables the charging hopper to be at the top all the time, and the discharging nozzle to be at the bottom, which creates a great convenience for filling raw materials and unloading the end product from the grinding chamber [4].

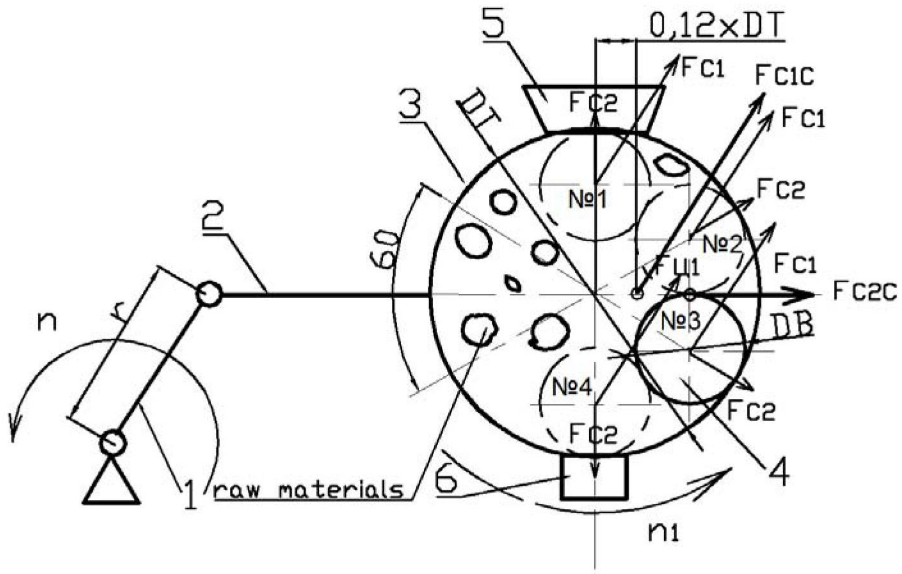

Figure 1 - Operation principle scheme of the centrifugal gyratory mill, crank-1, crank rod – carrier gear -2, grinding chamber -3, grinding body -4, charging hopper -5, discharging tube -6

Let us consider the motion of a cylindrical grinding body 4 with mass of *m* and diameter of D_B in a grinding chamber - tube 3 with an internal diameter of D_T when crank 1 rotates with a radius of *r* with a frequency of *n* (Fig. 1). When crank is rotated, the grinding body 4 is affected by:

1. Gravity force P = mg, always directed downwards.
2. Centrifugal force directed across the crank position and, together with the crank, rotating in the same direction with the same frequency of *n*.

$$F_{C1} = m * r * (\frac{\pi * n}{30})^2$$

Under the action of this force, the grinding body begins to move along the inner surface of the grinding chamber tube. The motion occurs along the circle with the radius $R_K = (D_T - D_B)/2$ in the same direction as the rotation of the crank.

The force of $\mathbf{F_{c1}}$ is directed along the tangent to the circumference of the grinding body motion. With this motion, the second centrifugal force $\mathbf{F_{c2}}$ appears that is directed along the radius of the grinding chamber tube, its value is equal to:

$$F_{C2} = m * R_K * (\frac{\pi * n_1}{30})^2$$

n_1 – is rotation frequency of the grinding body inside the grinding chamber, $n_1 << n$. The rotation of the grinding body inside the chamber is prevented by raw materials. It can be assumed that

$$n = 3 * n_1$$

The force always squeezes the grinding body against the wall of the tube in the grinding chamber. It can be seen from these considerations that in the general case, the grinding body is affected by three forces that are involved in the grinding of raw materials. The forces of **P** and $\mathbf{F_{C2}}$ squeeze and use up the raw material and the force of $\mathbf{F_{C1}}$ breaks up the raw materials.

We shall consider the interaction of several identical grinding bodies. It can be seen from Fig. 1 that all the grinding bodies are affected by the force $\mathbf{F_{c1}}$ and the gravity force **P**, grinding bodies occupy different positions in the tube of the grinding chamber, therefore only one body can occupy such position under which its force Fc1 is directed along the tangent to the circumference of the motion, and it is a fully movable force only for that body. It is the body 3 in Fig. 2. For the remaining bodies, the force $\mathbf{F_{C1}}$ is partly movable, they are bodies 2 and 4 opposing the movement of body 1. In this case, it turns out that only one grinding body is fully driven, and acts as the engine of the entire system of grinding bodies. Some bodies assist it, some of them counteract. Certainly, the rotation of the entire system of grinding bodies runs at a frequency n_1 which is much inferior in magnitude to the frequency n, since there is an opposition to some grinding bodies and raw materials in this case. It can be seen from practical survey that the rotational frequency n_1 is approximately S = 4-6 times lower than the value of the frequency n, substantial fluctuation of the value depends on n (the greater n the smaller the S), the hardness of the raw material and etc. Under diverging of the rotation frequencies, all grinding bodies of the system in order are found in the role of an engine of the entire system.

For the successful operation of the grinding bodies system, it is very important to ensure their movement with force against the tube walls, but taking into account $n_1 << n$, the condition of constant force of the grinding bodies against the tube walls is not always fulfilled, especially in the course of the upper point passage. In this case, it should be ensured that the upper grinding body cannot fall to the centre of the tube, which instantly causes the entire rhythm of the grinding bodies motion. It is possible to provide by selecting the geometric parameters - D_B, D_T and the number of grinding bodies - N. It is clear from practical experience that the optimal value of N = 4, at N = 3 and N = 5, the efficiency of grinding bodies motion deteriorates. It also follows from the experiments to choose the parameters D_B and D_T from the following ratio D_T/D_B = 3.1 – 3.0.

Since forces $\mathbf{F_{c2}}$ are forwarded to all directions, their vector sum is small and its effect on the dynamical stability of the mill will not be so noticeable, but these centrifugal forces are not balanced and have an impact on the device workability. We shall determine their approximate value. We shall take the ratio of D_T/D_B = 3,1. It can be seen from Fig. 1 that forces F_{C2} of bodies 1 and 4 are directed in diametrically opposite directions at this ratio, and they are self-destructed. Forces $F_{C2}$of bodies 2 and 3 are directed at the angle of 60^0. Their summing vector force is equal to:

$$F_{C2C} = 2 * F_{C2} * \cos 30^0 = 1{,}73 * F_{C2}$$

The force of $\mathbf{F_{C2C}}$ passes through the centre of the grinding chamber and rotates at a frequency of n_1.

The summing force F_{C1} is equal to their sum since all the forces are equal and forwarded to one direction:

$$F_{C1C} = 4 * F_{C1}$$

The point of application of the force is at a distance of $l = 0.12 \bullet D_T$ from the centre of the grinding chamber. This point rotates at a frequency of n_1

We shall carry out a force analysis of the scheme taking into account the movement of grinding bodies in the grinding chambers. The design parameters of the mill: tube diameter is D_T = 140 mm, pig diameter is D_B = 45 mm, crank length is r = 15 mm, rotation frequency is n = 500 min^{-1}, frequency is n_1 =170 min^{-1}, pig weight is m = 7 kg, crank weight is $m_к$ = 20 kg, grinding chamber-tube weight is m_T = 10 kg, number of tubes is 2 pcs.

Let us define the total centrifugal force F_{C1O} according to the formula:

$$F_{C1O} = (8 * m + 2 * m_T + m_K) * r * (\frac{\pi * n}{30})^2 = 3600..H$$

The force can be counterbalanced (destroyed) by installing the counter-weight.

Centrifugal forces F_{C1} and F_{C2} of one disc

$$F_{C1} = m * r * (\frac{\pi * n}{30})^2 = 262{,}5..H$$

$$R_K = \frac{D_T - D_B}{2} = \frac{0{,}14 - 0{,}045}{2} = 0{,}0475..м$$ - rolling radius of the grinding body

$$F_{C2} = m * R_K * (\frac{\pi * n_1}{30})^2 = 105,27..H$$

Unbalanced force of F_{C2C} from the rotation of pigs in the tube.

$$F_{C2C} = 1,73 * F_{C2} = 182,1..H$$

Unbalanced moment from the movement of pigs in the tube.

$$M_H = (0,12 * D_T) * 4 * F_{C1} = 17,6..Нм$$

It can be seen from the calculations that the unbalanced dynamic force and moment are not large in comparison with the total centrifugal force, but their impact ought to be taken into account in design of the mill. In particular, it is necessary to ensure sufficient joints rigidity and their good lubrication to reduce wearout. The calculation does not take into account the influence of raw materials, which has a balancing effect, since its basis weight is in the grinding chamber on the opposite side of the grinding bodies, but the mass of raw materials is much less than the mass of the steel grinding bodies.

At present, there is a basic design of the mill operating on the described principle [7].

The scheme of the mill has a number of serious shortcomings preventing wide spread of mills of such type (Figure 2). It is a dynamical unbalance of the mill, large metal capacity of the structure, its complexity and cost, there is an excessive kinematical connection (cranks are rotated simultaneously by a crank rod and gearwheels), which creates problems in the assembly and exploitation. The scheme of the mill is shown in the Fig. 2[6].

It consists of two identical cranks 4 connected with the carrier gear-crank rod 5 which contain parallelogram together with the mounting rack 7. The grinding chamber 1 is fixed on the crank rod 5. Cranks have counterweights 6. Cranks 4 are driven by the engine 2 through gearwheels 3.

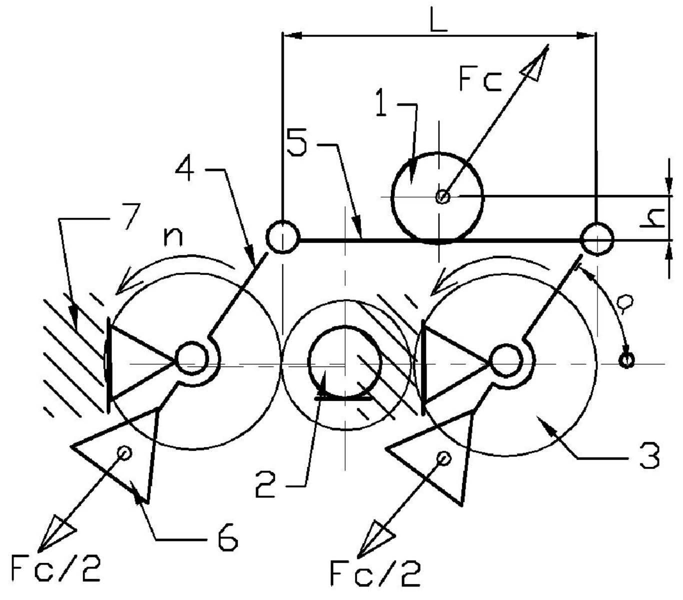

Figure 2 - Basic scheme of a centrifugal mill

In order to fully balance the mechanism, it is necessary that the vector sum of all the static forces applied to the mechanism (1), the rotational moments sum of these forces (2), the vector sum of all the dynamic forces (3) and the rotational moments sum from these forces (4) become zero, i.e., the next condition should be fulfilled:

$$\Sigma P_i = 0 \ (1); \ \Sigma M_i = 0 \ (2); \ \Sigma F_{qi} = 0 \ (3); \ \Sigma M_{qi} = 0 \quad (4)$$

In the abovementioned scheme, condition (4) is not always satisfied. When the condition (3) is satisfied, the centrifugal force of the grinding chamber Fc should be equalized by the centrifugal forces of the two counterweights, hence the force of one counterweight is equal to Fc/2. The grinding chamber is installed in the centre of the crank rod 5, length of which is equal to L (Figure 2). The gravity centre of the grinding chamber 1 in the given scheme is always raised by amount h towards the crank rod line 5. It is dictated by the design requirements for free passage of the counterweights. The condition (4) for the scheme is as follows:

$$\frac{F_C}{2} * L * \sin\alpha - F_C * \left[\frac{L}{2} * \sin\alpha + h * \cos\alpha\right] = 0$$

The given equation becomes zero only if h = 0 either $\alpha = 90^0$ or 270^0.

At $\alpha = 0..or..180^0$ we have an unbalanced moment $M = F_Ц \bullet h$. Let us take the following data for calculation: $\mathbf{F_c}$=500 H; L= 0.8m; h=0.1 m. Figure 3 shows the diagram of formula 5.

Table 1

Angles of rotation, degrees	0	30	60	90	120	150	180	240	270	300	360
Centrifugal moment, Nm	-50	-43	-25	0	25	43	50	25	0	-25	-50

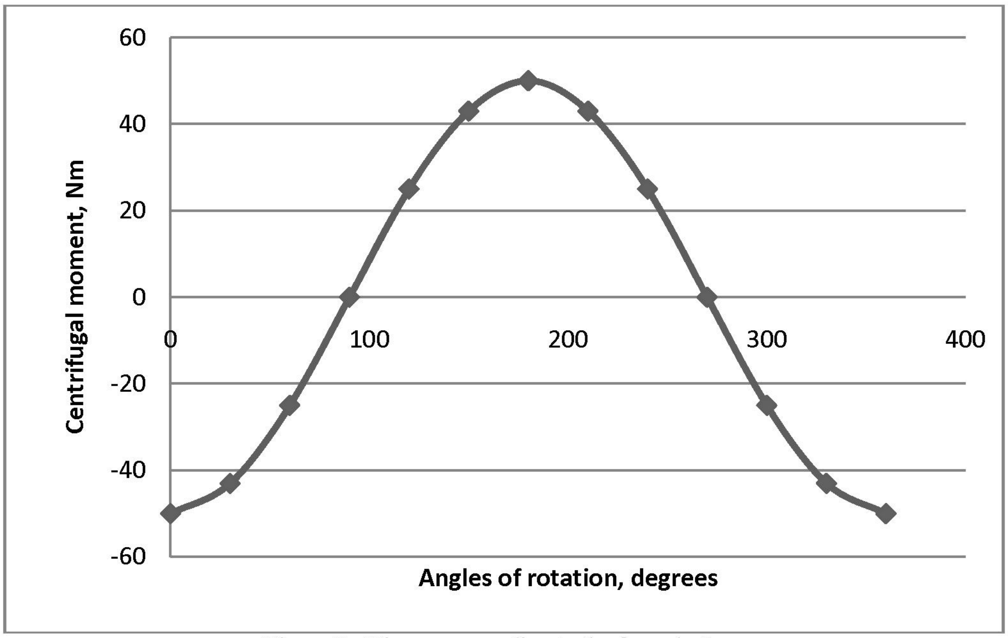

Figure 3 - Diagram according to the formula 5

3. DISCUSSION. CENTRIFUGAL GYRATORY MILL OF A COULISSE TYPE

In [9, 10] the following scheme is proposed (Figure 4). Two prototype models have been produced (Figures 5 and 6).

Practical mills tests were carried out in the testing area of the Scientific Research Institute of Mineral Processing of the National Centre for Processing Mineral Resources of the Republic of Kazakhstan. Features of the mills are shown in Table 2.

Table 2 - Characteristic of a mill

Mill	Weight, kg	Overall dimension, mm	Capacity, kW/ton	Number of grinding chambers	Pig diameter, mm	Outer diameter of grinding chamber, mm	Rotation frequency, min^{-1}	Производительность по руде, кг/час	Input size, mm	Dispersability of end product, µm
1	350	1000x900x800	2,2	2	45	140	500	320	20-30	20..70
2	380 0	1600x1200x1000	22	4	70	220	450	3000	30-40	20..70

According to the indicators, it can be noticed that the proposed mills have a specific output of 140 kg/kW or 8 kW/ton of production. According to this indicator, proposed mills exceed the ball mills by 2 times.

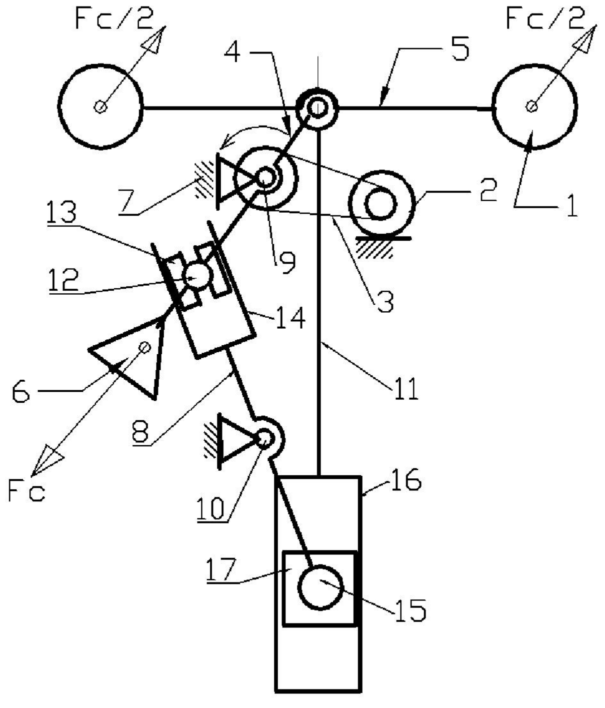

Figure 4 - Schematic diagram of the proposed centrifugal gyratory mill

The given scheme applies a coulisse mechanism. The two grinding chambers 1 are mounted symmetrically on the crank rod - carrier gear 5 which engage with the crank 4. The crank 4 is rotated by the engine 2 around the axis 9 through the belt transmission 3. At the opposite end of the crank 4, there is a counterweight 6 and a cylindrical finger 12 which engages with the fork 14 mounted on the link 8 through the inserts 13. At the opposite end of the coulisse 8 there is a straight pin 15. The coulisse 8 rotates about the axis 10. The pin 15 interacts with the fork 16 through the insert 17. The fork 16 is installed on the rod 11 rigidly connected to the crank rod - carrier gear 5 [7].

In this scheme, the theoretical balance of the mechanism is obtained (grinding chambers are considered as whole bodies). There are significant design achievements: there is one crank shaft, there is no excessive coupling, no need for gears which greatly simplifies the design.

The mill is distinguished by a low level of metal consumption. As a comparison, a ball mill with the capacity of 10 tons/hour weighs 30 tons, the weight of the proposed mill with the same capacity will be at the level of 8-10 tons.

The mill has a low level of structural complexity. Presently existing gyratory centrifugal mills described above are more sophistic, for example, the option (Figure 3) has two eccentric shafts, 14 bearings, 3 gearwheels. The proposed mill has 1 eccentric shaft, 5 bearings, no gearwheels. Weight is reduced by 1.5 times.

Mill design simplification and reduction of its metal consumption enabled to reduce the cost of the mill in comparison with the ball mill by approximately 3 times, in contrast to the existing centrifugal mills by a factor of 1.5. The mill has high maintainability. It does not require rigid protection of the grinding chambers, they are quickly replaced with new ones under the severe wear. The cost of grinding chambers is not high, they are made from standard steel tubes of small diameter.

Data from the experiments demonstrate that mill productivity is affected by shaft rotation frequency, grinding chamber volume, crank length, and inclination angle of the grinding chambers. Shaft rotation frequency, grinding chambers length, the hardness of the grinding bodies and their asperity, mass of grinding bodies, inclination angle of the grinding chambers produce effect on the dispersion of the obtained product.

Tests were carried out (Mill No. 1). Raw-barite to determine the mill productivity from the shaft rotation frequency. The results of the test are summarized in Table 3.

Table 3 - Mill productivity from rotation frequency

Rotation frequency, min^{-1}	300	350	400	500
Productivity, kg/hour	130	150	190	350

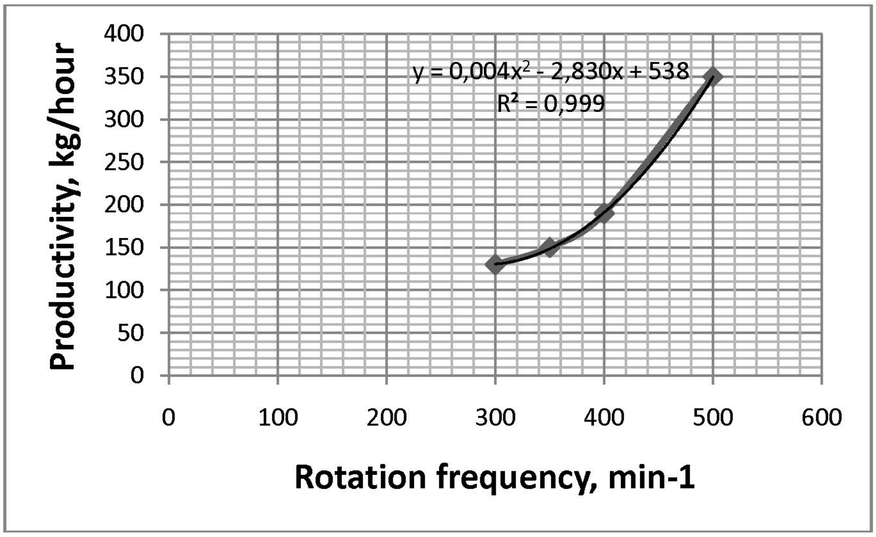

Figure 5 - Dependence diagram of the productivity from the shaft rotation frequency.

Figure 5 shows a plot of -3 points, a regression equation is taken, a quadratic function of the dependence of productivity on the rotational speed:

$$Y = 0{,}0049 * x^2 - 2{,}8309 * x + 538$$

Coefficient of determination $R^2 = 0{,}9999$

It became clear from tests for durability that the weaker places of the mill are the fork and especially the finger and groove into which it enters, which are subject to rapid wear. These elements should be made of high-strength steels and ensure good lubrication.

Tests of the mills showed their economy in energy consumption, however, they revealed drawbacks, one of the main is the lack of durability of separate units, the necessity for a lubrication system.

Figures 6, 7, 8 show the assembly drawing of the corrected mill. The coulisse joint is considerably strengthened in the design, self-contained lubricators are installed, the frame is reinforced and etc.

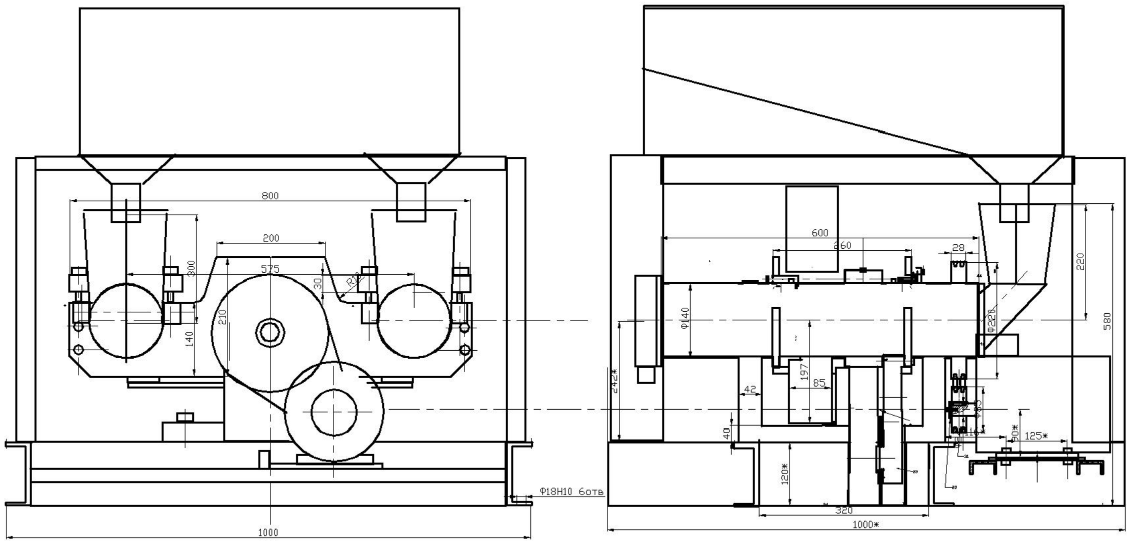

Figure 6- Drawing: general view of mill number 1

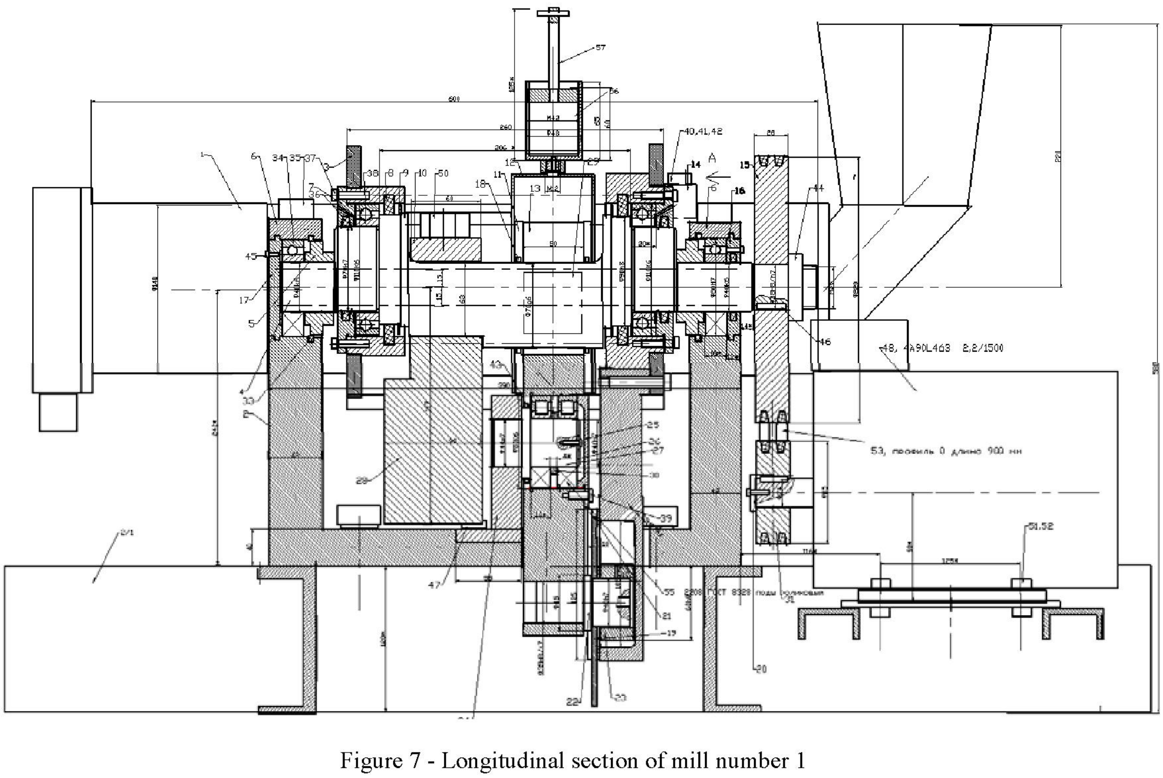

Figure 7 - Longitudinal section of mill number 1

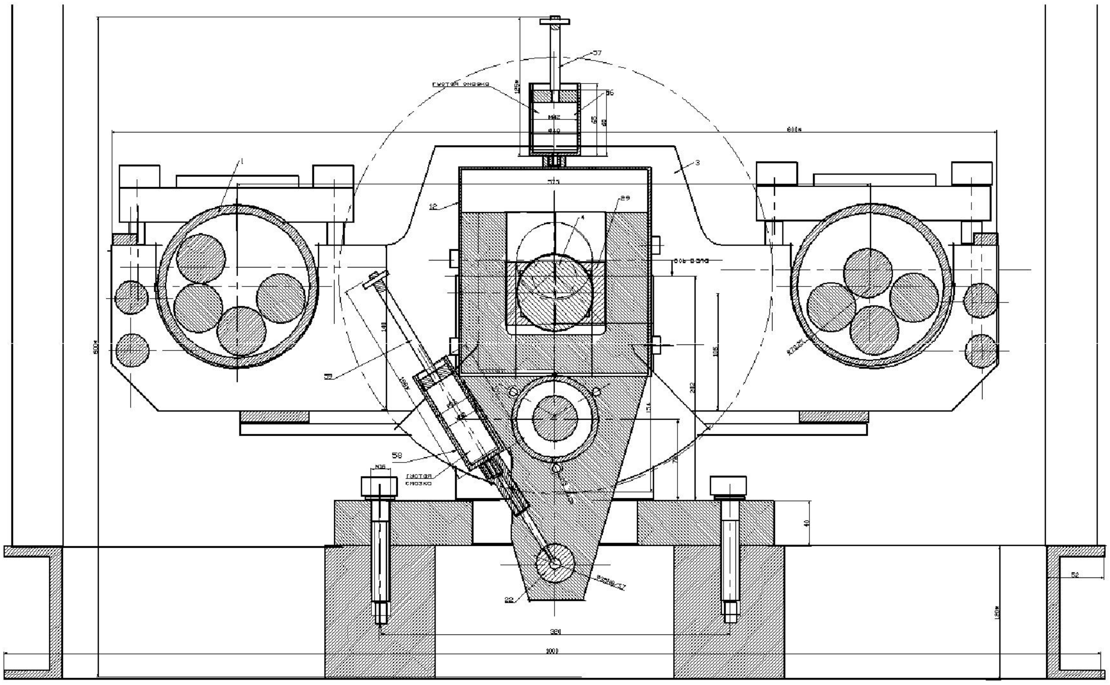

Figure 8 - Cross-section of mill No.1

The coulisse is substantially strengthened (Figure 10), hardened steel plates with high hardness are installed with the inserts at the point of interface. 4 grinding bodies are put in the grinding chambers, and they have different lengths and a smaller diameter is made at the end. It accelerates the retraction of large pieces of raw material into the grinding zone.

In the future, the authors are going to create a mill without a counterweight that will increase the efficiency of the equipment [10].

Conclusion: the original design of the centrifugal mill on the basis of coulisse mechanism has been proposed, full-scale tests of two patterns have been conducted, a specific power consumption level of 8 kW/ton of ore has been obtained, which is two times better than ball mills.

REFERENCES

[1] GOST 10141-91 "Mills rod and spherical" General technical requirements.

[2] Andreyev S. E. Crushing, crushing and grokhocheniye of useful minerals. M.: Subsoil, **1966**. 395 p.

[3] Bogdanov V. S. Spherical drum mills. Belgorod, **2002**. 258 p.

[4] Application of centrifugal and shock mills of "MTs" at a cement grinding the Electronic resource / V.N. Kushka, A.V. Artamonov, M.S. Garkavi, E.A. Ashurkova, E.E. Bundina.

Access mode: http://www.uralomega.ru/infonews/articles/cemmill

[5] Askarov E.S. Centrifugal giratsionny mills - features of a design and calculation/M. The messenger of mechanical engineering is M.: **2008**. N. 2. P 86-88.

[6] Askarov E.S of RK 26229 patent. A centrifugal mill without counterbalance, MPK V02S17/08, б. N.10 from 10/15/2012.

[7] Arinova D.B. Askarov of E.S. Zhankeldi. A.Zh. Konstruktion centrofugal– a giratsionny mill with low consumption of elektroenergiya//Cars. Technology. Materials. Bulgaria. 2017. No. 5. Page 374-376.

[8] Askarov E.S. Bertayev K.S. Azimbekov M.K. Utelbayev O.B. Centrifugal giratsionny mills with low energy consumption//the Industry of Kazakhstan. **2006**. No. 4, P 81-86.

[9] Askarov E.S. Centrifugial-gyrational mill with a coulisse drive mechanism // Allerton press. Russian engineering research (USA). **2003**. № 9. P.53-56.

[10] Askarov E.S. Centrifugial-gyrational mill with no countrweight // Allerton press. Russian engineering research (USA), № 3, **2013**, p.150-151.

[11] RK 6175, MPK V02S17/08 patent Centrifugal link single-shaft melknitsa // Askarov E.S., bulletin N. 6, 6/15/2001.

Д.Б.Аринов[1], Е.С.Аскаров[1], Г.Попов[2]

[1] Қ.И. Сәтбаев атындағы Казақ ұлттық зерттеу техникалық университеті, "Стандарттау, сертификаттау және машина жасау технологиясы" кафедрасы, Алматы, Қазақстан;
[2]София техникалық университеті, София, Болгария.

КУЛИСТІ ТИПТІ ЦЕНТРДЕН ТЕКПІШ – ГИРАЦИОНДЫ ДИІРМЕННІҢ КОНСТРУКЦИЯСЫН ЗЕРТТЕУ ЖӘНЕ СЫНАУ

Аннотация. Жыл сайын әлемде миллиардтаған тонна шикізат уату арқылы өнделеді. Бұл процесс энергияны көп қажет етеді. Тау – кен өңдеу өндіріс алаңдарында көбінесе шарлы типты диірмендер қолданылады. Оларды пайдаланудың тарихы 200 жылдам астам уақытты құрайды.

Қазіргі таңда бұл жағдай күрт өзгеріс алды, себебі энергияның үнемді пайдалануы диірменнің жұмыс істеу қабылетінің негізгі көрсеткіштерінің бірі болып саналады. Өйткені, энергия көзі қымбаттады, экологиялық ахуалдар пайда болды, сонымен қатар рудадағы пайдалы қазбалардың мөлшері азайды. Сол себепті энергияны үнемдейтін диірменді ойлап табу актуалды сурақтардың бірі болып табылады.

Центрленген - гирационды диірмен әртүрлі минералды шикізат көзін уатуға арналған диірмен. Бұл типті диірмендер бұрыннан белгілі және жұмыс істеу барысында жақсы нәтижелер көрсетті. Диірменнің негізгі ерекшелігі электрқуатын тиімді пайдалану болып саналады.

Жазылған жұмыста кулисті механизм негізі болатын центрленген - гирационды диірменнің конструкциясы зерттелген. Бұл диірменнің анық біраз артықшылықтары бар: конструкцияның оңайлатуы, жоғары динамикалық тұрақтылығы, энергия көзін екі есе аз пайдалануы және т.б.

Ең алғаш рет тәжірибелерді «Пайдалы казбаларды байыту Ғылыми – зерттеу институтының» полигонында жүргізілген. Ол Қазақстан Республикасының минералды ресурстарын өңдейтін ұлттық центріне енеді. Диірменнің жұмыс істеу принципі зерттеліп, цилиндрлі ұнтақтағыш камералардың параллельді жазықтық арқылы қозғалыс жасап, камералардың сыртқы диаметрі бойынша кривошиптің ұзындығына сәйкес қозғалады. Центрден тепкіш күштің мәні, салмақсыз динамикалық күштер мен моменттер, сонымен қатар күштік анализ жасалған.

Ұсынылып отырған диірменді зерттеу нәтижесінде өнімділіктің үлестік көрсеткішібір тонна өнімге 140 кг/кВт немесе 8 КВт құрайды. Осы көрсеткіштің арқасында зерттеліп отырған диірмен шарлы диірменнен 2 есе артық. Бұл сұлбада механизмдердің теориялық теңдесуі алынған. Елеулі конструктивті жетістіктер бар: бір кривошипті білік, тісті дөңгелектерді қолдануды талап етпейді, артық байланыс жоқ.

Металл сыйымдылық дәрежесі төмен. Мысалға, өнімділігі 10 т/сағ болатын шарлы диірменнің салмағы 30 тонна болса, ал ұсынылып отырған диірмен дәл осындай өнімділікте 8 – 10 тонна салмаққа болады. Сонымен қатар центрленген – гирационды диірмен конструкциясы бойынша да аса күрделі есем. Осы жағдайларды ескере отырып диірменнің өзқұндылығының арзан болуын айтуға болады, мысалы, шарлы диірменмен салыстырғанда 3 есеге, казіргі таңда қолданылып жатқан центрленген диірмендермен салыстырғанда 1,5 есеге төмен. Сонымен қатар диірменді жөндеу, жөндеуге жарамдылық жұмыстары қиындықсыз жүргізіледі.

Жасалынған жұмыстардың нәтижелері тау – кен орындар мен байыту фабрикаларында кеңінен қолдануы ықтимал.

Нәтижелердің ғылыми жаңалығы центрленген – гирационды диірменнің конструкциясын зерттеп, диірменде өтетін процестерді, яғни ұнтақтау, энергосыйымдылықты, металлсыйымдылықты және диірменнің өнімділігін оңтайлы процестер қатарына енгізу.

Эксперименталды және есептеу, сонымен қатар рационалды конструктивті және технологиялық параметрлер негізінде, диірменнің металсыйымдылық көрсеткіші жоғары емес екендігі сипатталып, диірменнің өзқұндылығының арзан болуын айтуға болады, мысалы, шарлы диірменмен салыстырғанда 3 есеге, казіргі таңда қолданылып жатқан центрленген диірмендермен салыстырғанда 1,5 есеге төмен. Сонымен қатар диірменді жөндеуге жарамдылық жұмыстары қиындықсыз жүргізіледі. Ең негізгі көрсеткіші болып - бұл энергияны ұтымды пайдалану көрсеткіші басты рөл атқарады.

Түйін сөздер: минералдық ресурстар, энергия тұтынуы, металсыйымдылық центрленген - гирационды, ұсақтау, диірмен, конструкциясы, өнімділік.

УДК 621.926

Д.Б.Аринова[1], Е.С.Аскаров[1], Г.Попов[2]

[1]Казахский национальный исследовательский технический университет им. К.И. Сатпаева,
Кафедра «Стандартизация, сертификация и технология машиностроения», Алматы, Казахстан.
[2]Технический университет Софья, город Софья, Болгария.

ИССЛЕДОВАНИЕ И ИСПЫТАНИЕ КОНСТРУКЦИИ ЦЕНТРОБЕЖНО-ГИРАЦИОННОЙ МЕЛЬНИЦЫ КУЛИСНОГО ТИПА

Аннотация. Каждый год в мире перемалывается миллиарды тонн минерального сырья. Процесс измельчения требует огромного количества энергии. На горнорудных предприятиях в основном используют мельницы шарового типа, история использования таких мельниц насчитывает более 200 лет.

В настоящее время ситуация изменилась, энергоэффективность становится важнейшим показателем работы мельницы, так как энергия дорожает, значительно повысился статус экологических проблем, содержание полезных ископаемых в руде уменьшается. Вопрос создания энергоэффективных мельниц становится очень актуальным.

Центробежно- гирационные мельницы предназначены для перемола различного минерального сырья. Мельницы подобного типа известны уже достаточно давно и показали неплохие результаты в работе, одним из основных достоинств этих мельниц является пониженное потребление электроэнергии.

В данной работе исследуется конструкция центробежно- гирационной мельницы на базе кулисного механизма. Мельница имеет ряд преимуществ перед аналогами: упрощение конструкции, высокая динамическая устойчивость, затраты энергии уменьшены в 2 раза и т.д.

Впервые практические испытания мельниц проводились на полигоне Научно - исследовательского института обогащения полезных ископаемых Национального центра переработки минеральных ресурсов Республики Казахстан. Исследован принцип работы мельницы, который заключается в плоско - параллельном перемещении цилиндрических помольных камер – труб в плоскости перпендикулярной их оси, при котором каждая точка помольной камеры движется по окружности с радиусом равным длине кривошипа r механизма мельницы [5]. Рассчитаны центробежная сила противовесов, неуравновешенная динамические сила и моменты, проведен силовой анализ.

Из показателей исследования видно, что предлагаемые мельницы имеют показатель удельной производительности равный 140 кг/кВт или 8 квт на тонну продукции. По этому показателю предлагаемые мельницы превосходят шаровые мельницы в 2 раза [3]. В этой схеме получена теоретическая уравновешенность механизма. Имеются существенные конструктивные достижения: имеется один кривошипный вал, нет избыточной связи, не требуется применения зубчатых колес, что значительно упростило конструкцию.

Мельница отличается невысоким уровнем металлоемкости . Для сравнения скажем, что шаровая мельница производительностью 10 тонн/час весит 30 тонн, вес предлагаемой мельницы с такой же производительностью будет на уровне 8-10 тонн. Мельница имеет невысокий уровень сложности конструкции. Упрощение конструкции мельницы и уменьшение ее металлоемкости позволило уменьшить стоимость мельницы по сравнению с шаровыми примерно в 3 раза, по сравнению с существующими центробежными мельницами в 1,5 раза [4]. Мельница имеет высокую ремонтопригодность.

Результаты представленной работы перспективны для внедрения на предприятиях горнодобывающей и обогатительной промышленности Казахстана и могут быть использованы в горно - обогатительных комбинатах зарубежных стран.

Новизна полученных результатов заключается в создании и исследовании конструкций центробежно – гирационной мельницы, при которых обеспечивается оптимальный процесс помола, энергоемкость, металлоемкость и производительность мельницы.

На основе расчетов и экспериментальных данных, а также в определении её рациональных конструктивных и технологических параметров. Выявлено, что в процессе опытно - промышленного периода мельницы на полигоне Государственного научно- производственного объединения промышленной экологии «Казмеханобр» (Алматы), входящего в состав Национального центра по комплексной переработке минерального сырья Республики Казахстан, что мельница отличается невысоким уровнем металлоемкости, имеет невысокий уровень сложности конструкции, тем самым уменьшается стоимость мельницы по сравнению с шаровыми примерно в 3 раза, по сравнению с существующими центробежными мельницами в 1,5 раза. Мельница имеет высокую ремонтопригодность. Испытания мельниц показали их экономичность в потреблении энергии, что является самым главным показателем. А также показатель удельной производительности равный 140 кг/кВт или 8 квт на тонну продукции (в процессе испытания были использованы разные виды сырья) [8].

Ключевые слова: центробежно-гирационная мельница, измельчение минеральных ресурсов, металлоемкость, энергопотребление, конструкция, производительность.