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New and More Effective Grinding Bodies for Drum Mills

Alternative of the Spherical Grinding Bodies

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***Abstract*— An analysis of the work of drum mills, which use spherical grinding bodies. Referred to the unaccustomed activity of spherical bodies for crushing grinding materials. Proposed is a new form of grinding bodies, which also has spherical surfaces, but have crush edges. The following are experimental results obtained with the new grinding bodies of tests Bond Mill. The new bodies have a number of advantages over currently used spherical bodies. Available for every type of grinding material to be used specifically shaped body and thus to optimize the grinding process.**

***Keywords*— Relo body, Drum Mill, Reuleaux Tetrahedron, Ball Mill.**

I. INTRODUCTION

Since 1864 in the United States, and 1867 in Germany, started grinding materials, in particular minerals, by means of spherical grinding bodies - balls. Today, grinding of ores and most other materials with grinding bodies of spherical shape is one of the largest industries in the world. The reason is that more than 100 years to exhaust the rich ore deposits and having the metals to be extracted from ores with a very low percentage of metal. So ubiquitous passes to work with metal concentrates in which the artificially increased percentage of metal.
Mass these concentrates were prepared having the following operations:
1. Crushing of ore crushers to set size - in tens of millimeters.
2. Milling of the crushed ore to a particle size in the tens of microns.
3. Separation of metal particles - by flotation or other means.
The grinding of the ore is realized most commonly using a drum mill, used to contain a certain ball charge - usually mill filled with balls to 40-50% of its volume. During operation of the mill is periodic therein to add new portions of the balls. The world average cost of balls is about 0,9-1,1 kg for 1t ground ore. It turns out that the grinding bodies are an ever dwindling consumable for mining enrichment industry. So, from a business perspective, the grinding bodies are ideal device for business!
Without them, cannot, there is a continuing need for new quantities, and the continued impoverishment of ore in the world requires the production of ever larger amounts of grinding bodies, because poorer ores require digging and grinding of increasingly large amounts of ore.
According to our research for one year, the world produces about 30 million tons grinding bodies, which they defined as the mass finished metal product in the world!

The analysis of the work of drum mills, which we conducted of our position in the constructors forging machines [6] showed that the drum mills are inherently multitap forging machines (hammers with many percussion parts) free percussion parts, such as the role of percussion parts play spherical balls in the mill. Relies on spherical bodies to splinter grinding materials measuring less than 3 mm and then grind them to a particle size tens of microns. In this case we meet with striking disparity of resources and objectives - spherical bodies are used for crushing coarse ore that is unfamiliar to them work! Throughout labor and industrial history of humanity crushing materials is carried out by pressure or shock, which are realized by tool edge, often shaped like a wedge!

Used in the past 8000 years hand-held hammers are mainly two types - one with flat bumper - for forging and download plastic metals and others are wedge bumper - for crushing materials. Hammer, which striking part is a metal sphere, is found only in the areas behind the Arctic Circle! Used by some hunters of fur animals - of killing a live animal, the goal is not to damage his expensive fur. It turns out that with a tool in the shape of a sphere, which is used to avoid damaging the animal hair in drum mills ground and most hard rock breeds. Naturally, in the process of crushing the spherical surfaces of the field, except that it will work inefficiently, will fail quickly and this is necessary to place in new mills portions spherical balls.

We assume that this illogical application of spherical bodies - to crush, but to digest, has influenced many in-depth study of G. Chad Norris [1]. In 1954 he and his associates have conducted many studies into the grinding ability of all known forms of his then grinding bodies such as spheres, cubes, spherical cubes (spheres with six flat sides), cylinders, discs and other options. Indisputably proves that for grinding spheres superior in all respects other grinding bodies. In practice, the search for new grinding bodies are suspended, moreover, prove that the fields can grind materials to a fineness of 0,0001 mm.

Now we will discuss in more detail the grinding bodies in the shape of a sphere. Field is the geometric body with the smallest outer surface to the other geometric volume bodies in equal volumes! At the same time the area has the highest grinding capacity than other geometric bodies due to its maximum roundness and symmetry, because it is a body of constant width. For the past 150 years spherical bodies are practically fully tested, were tested and developed high technology for mass production of high quality grinding bodies. Already made the ceiling of the capabilities of the spherical grinding bodies! They are produced mostly by stamping presses or forging machines by casting and roll. To achieve a higher wear balls cured and has achieved increasing the stiffness to the center of the balls. For this purpose the alloy, usually chrome steels, which, together with the heat treatment, further increases the cost of the grinding bodies.

We set ourselves the task to develop new Milling body to keep the grinding ability of spherical bodies, and their price, but to digest more efficiently. Furthermore, the new body should have the same mass, as of now used areas. For this purpose put together Milling body shape near spheroidal tetrahedron. Spheroidal tetrahedron is not very well known geometric volume figure who called Reuleaux Tetrahedron - named after the famous German engineer Franz Reuleaux (1829-1905).

This body is composed of parts of 4 fields, but have a larger radius than the radius of the analogue volume sphere: R RT = 2,1487 R SPH. For this reason the new Milling body in exactly geometrically embodiment, has an outer surface with 9.35% greater than the outer surface of the analogue domain in equal volumes and masses. In mass production of these tetrahedron stamping, casting or rolling this difference will decrease, but will always be not less than 7.5% [2]. Most outer surface is a prerequisite for more productive grinding, because the grinding will now involved grinding surface having a larger area. And most importantly - in this figure retain the spherical surfaces, and both proved Norris, they have the best milling qualities. In Figure 1 are given the first examples of spheroidal tetrahedron, which are made by us.

a/.

b/.

Fig. 1: a /. Geometric model of spheroidal tetrahedron a height of 85 mm, made of aluminum alloy at the Technical University, Sofia, 2006, 9.35% more surface area of a sphere with the same volume; b /. Steel spheroidal tetrahedron industrial grinding, height 82 mm, an analogue of a sphere having a diameter of 80 mm, made by molding in a hot mechanical press, 2008, 8.4% more surface area of a sphere having the same volume.

The results of the comparative grinding in the drum mill with spherical balls and similar spheroidal tetrahedron with a difference in masses to + 1%, showing an almost complete line of surface increased with the increase of the tetrahedron of ground to 80 micron size particles. In the case produced by hot stamping mechanical press spheroidal tetrahedron with unit weight 2,104 kg, have a larger area than equivalent spherical balls by 8.4%.

Averaged results of comparative experiments with tetrahedron and spherical balls show an increase in the relative performance of the tetrahedron in class 80 microns to 8.45% compared to the spherical balls. The other major effect of the formation of the new body of 4 parts of spheres is that these spherical parts upon contact form curved edges - 6 and 4 top. The presence of edges and vertices leading to a 100% increase in productivity for the fragmentation of coarse particle ore! This is because for the first time a combined Milling body - 4 grinding spherical surfaces and with 10 breaking elements - 6 edges and 4 top. Introducing the grinding body with edges placed Milling merits of a new unit at a high level in technological and operational development of the product. For more

convenient called these new bodies with the name Relo body.

Spherical bodies can vary only one parameter - radius of the sphere and this severely limits the ability of the spherical body to adapt to specific conditions. Quite different is the situation in spheroidal tetrahedron. In addition to the radius of the spherical surfaces can be formed as various combinations of shaping the vertices and edges. It is evident that the spherical surfaces should be maintained as much as possible in a larger percentage of the surface of the new body. The tips may be sharp, rounded or chamfered[3]. The edges may also be sharp, rounded or chamfered. For example, after discussion with specialists-technologists from four cement companies the potential of new bodies for grinding cement clinker specify that in the cement industry is often necessary to digestion is performed at temperatures of milled material above 100˚C, which is a prerequisite for accelerated damage to the hull of the mills. For this construction Milling body to fully satisfy these requirements [5] and is designed for dry grinding of cement clinker, limestone, coal, petroleum coke, lime and similar materials.
Similarly approached and to construct the grinding bodies for different types of ores. Created a whole range of bodies model M [4] milling of ores and other materials. Our experience has led to the logical conclusion that it is possible for each type of grinding material to create optimal Milling body! Modern industry for the production of grinding bodies without problems can be adapted to the production and .various models grinding bodies. Of course, it is necessary to conduct a number of studies to clarify models grinding bodies that are optimal for grinding the material. With the introduction of the new grinding bodies move to a qualitatively new stage in the technologies of grinding materials in drum mills. We have already melling units of new generation!

II. EXPERIMENTAL SECTION

After Held in Mining and Geology University "St.. Ivan Rilski ", Sofia, tests of new grinding bodies with Bond Mill. We made a total of 285 the number of new grinding bodies model Relo body-C1, Fig. 2, five sizes, which are given in Table 1.

Spheres	D_1=38,10 mm	D_2=31,75 mm	D_3=25,40 mm	D_4=19,05 mm	D_5=15,87 mm
Spheres pcs.	43	67	10	71	94
Relo-C1 pcs.	43	67	10	71	94

Fig. 2: A comparison of two types of grinding bodies in the size of 5 - spherical and model Relo body-C1, used in the tests of the Bond Mill.

III. RESULTS AND DISCUSSION

The test results with different materials and with a pattern Relo body-C1 are shown in Table 2.

№	Material	Energy effect %	Produc-tivity effect %	Total effect %	Wi Spheres	Wi Realo-C1
1	Lime-stone	9,30	8,10	16,65	11,30	11,00
2	Coal	8,83	6,70	14,90	29,20	27,80
3	Clinker	13,50	16,30	27,60	14,60	13,60

Table 2

Additional tests conducted with the model body Milling Relo body-M1.1, intended for grinding soft ores, and the results are given in Table 3.

Fig. 3. Comparison of the two types of grinding bodies in the amount of 5 - spherical model and Relo body-M1.1, used in the tests of the Bond Mill.

Material	Energy effect %	Productivity effect %	Total effect %	Wi Spheres	Wi Realo-M1.1
leadzinc ore - soft	5,8	6,75	12,16	12,20	11,90

Table 3

Known methods for increasing the productivity of milling are three:
1. By increasing the size or quantity of the mills.
2. By changing the type of the mill for milling. Ball drum mill worth $ 10 million is replaced by a more productive roller mill worth $ 21 million.

3. By entering the new crushing plant to reduce the size of the grinding particles before they enter the mill. Currently the best industrial crushers crushed particles to a size of 5 mm. Fed into the mill at a particulate material increases the productivity in the grinding, but sharply increases the cost of crushing!

All three methods are accompanied by a million investment and considerable time, at least several months and assembly-adjusting operations of the new equipment.

We offer a fourth way to increase grinding in drum mills! The essence is simply to replace the current spherical grinding bodies offered by us - a form similar to spheroidal tetrahedron! So in practice will realize a zero investment, because someone will buy grinding bodies, and this at the same price, but due to the replacement will be a more efficient milling! No need to make any new costs! Nor new training of the staff to work with the new bodies!

The new technology of grinding - with new grinding bodies - has a positive environmental effect - it will reduce energy for grinding, i.e. reduced have other advantages that increase their attractiveness as the most appropriate Milling body for the mining industry!
Increased efficiency of digestion will lead to better use of even poorer ores. Currently the trend is in continuous increase in metal prices. For the past 20 years, the price of the iron is increased 4 times, and copper - 10 times! Given that our civilization is a metal, i.e., metals are the basis for its existence and development determines the extraction of metals such proceedings are without alternative.

According to data from the Internet annually worldwide digested:
1. Because there is no complete data how much ore is mined, will try indirectly to give an idea of the scale of the mining industry. In metallurgical furnaces annually pass over 100 billion tons ore concentrates - obtained by grinding.
2. Produced about 3.5 billion tons of cement, which is obtained by grinding the clinker to a size 90 microns.
3. Yield about 3.75 billion tons of coal, of which up to 80%, ie about three billion tons are burned at power plants. They also digest because power plants burn coal dust.
4. Grind millions of tons of building materials such as sand, clay minerals, lime and others.
5. Grind huge amounts of raw materials for paints and chemicals.
6. Grind the most diverse waste and other materials.

Another great advantage of the new grinding bodies, Relo bodies, to spherical grinding bodies is their greater density in the same volume - up to 12-15%. This higher density of arrangement is a further prerequisite for increased productivity in the grinding bodies Relo. Because it means increasing the number of working bodies and therefore we can expect and thus significantly increase productivity. Twice larger radius of the spherical surfaces, compared to the same area, creates a greater contact patch of Relo body with housing Drum Mill. For this reason, the rotation of the mill Relo body will climb and fall from a greater height than the analogous spherical body.

As a result drop down Relo body will blow with greater kinetic energy from such fields, ie will have a large crushing performance. Matter proves the fact that the center of gravity of Relo body is symmetric, to the height of the body. Thus Relo body turns by unbalanced center of gravity, leading to a more complex movement of the body in the mill, in comparison with the areas, and thereby increases the productivity of the crushing and grinding.

An important advantage of the bodies Relo emerged and technology of their production. Primarily Relo bodies are bodies of inconstant width, while the spheres are bodies of constant width. This distinction, inconstant width allows for accelerated cooling of some parts of their bodies Relo to other sections of them - cooling tempering. For example, while the areas cool and quenched uniformly, edges and vertices of the bodies Relo will cool down at a higher rate than the other surfaces. Eventually this leads to the production of larger quantities than 60%, hardened mass bodies Relo against hardened mass spherical bodies - hardened under the same conditions. This high rate allows us to use for grinding bodies cheap steel and cheap technologies for heat treatment by hardening only with tap water. Furthermore, in the production of cast bodies Relo possible gas bubbles (voids) will be centered at the center of the body.

These capabilities bodies Relo will positively affect their price!

IV. CONCLUSION

The test results of the new bodies show that with them it is possible to obtain savings electrical energy and increase the productivity of the drum mills with more than 10%. Their production is feasible with currently used technologies for mass production of grinding bodies are expected and additional benefits.

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