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Industrial Tests with Innovative Energy Saving Grinding Bodies

Dr. Eng. Petar Bodurov - pbodurov@mgu.bg

Eng. Vasil Genchev -genchev@tu-sofia-bg.com, Relo-B Ltd., Bulgaria

***Abstract*—There is an alternative of the spherical grinding bodies. Innovative grinding bodies have shown in university tests with Bond Mill lower values of the Fred Bond Wi index of the values obtained with spherical grinding bodies. These results are the basis for conducting industrial tests with innovative grinding bodies. Industrial tests clearly show the advantages of innovative grinding bodies compared to spherical grinding bodies - significantly, up to 90 % increase in productivity and greater reduction in energy costs for grinding - by about 40 %. Therefore we define these new grinding bodies as energy saving bodies.**

Keywords—innovative grinding bodies, spherical grinding bodies, Drum Mill, energy saving bodies.

1.Introduction Since 1864 in the USA and since 1867 in Germany has began grinding of materials such as ores and other minerals in drum mills with spherical grinding bodies. Today, in the world with billions of tons of ore, coal, cement clinker, limestone and other materials are being milled with spherical grinding bodies. A huge industry for mass production of that consumer was created, which has established itself as indispensable for milling in drum mills. Some data, set spherical grinding bodies as the largest scale by volume, finished metal product in the world. We assume that their global production reaches 30 million tons per year. Furthermore, for the needs of some industries, large quantities of ceramic grinding bodies are produced, also spherical in shape. Spherical grinding bodies have already reached the top of their development and breakthrough in conventional milling technology is only possible with radical change. We have developed a group of 7 innovative grinding bodies with a form different from spherical – two for "Dry" grinding process and five for "wet" grinding process. [1] [2] We accepted that any material can be used for optimal grinding body. University tests of the Mining and Geology University, Sofia, with the first body model "Reloe-C1 'of Bond Mill showed significantly lower index values of Fred Bond - Wi, than those obtained with spherical grinding bodies. The results obtained for various materials are given in Table.1. [3]

Table 1

№	Material	Wi Spheres	Wi Reloe-C1
1	Limestone	11,30	11,00
2	Coal	29,20	27,80
3	Cement Clinker	14,60	13,60

Lower indexes of the Wi s values how that grinding of the materials indicated above with innovative units will always be realized with less power consumption. Therefore we called the new bodies also energy saving bodies. It should be noted that tests with the Bond Mill are held in almost idealized conditions and the materials have particle size not greater than 3,2 mm. For this reason we expected to get better results when conducting industrial tests.

2. Experimental Section

When conducting industrial tests we set 3 tasks as objectives:

- Identifying performance in grinding - t / h;
- Determining energy consumption of 1 t material - kWh / t;
- Establishing changes in the shape of grinding bodies after continuous milling.

2A. **Place of testing and grounds**: dressing plant owned by the company "Rudmetal" AD RUDOZEM - under a Contract dated 14.03.2016, between "Relo B" Ltd. and "Rudmetal" AD for production, delivery and industrial tests of energy saving bodies (ESB).

2B. **Facilities for conducting the tests**: Two number drum mills model MQG 1530 manufactured in China, with diameter of 1500 mm and length 3500 mm. The mills have a wear-resistant inner lining with thickness 35 mm and have two oppositely arranged rectangular lids. The enclosure/lining has a variable thickness. Each mill is powered by a motor-driven power 75 kW. Flotation system was delivered and installed by the company "GORMASHEKSPORT", city of Novosibirsk, Russia.

All data required for operation of the facilities of the flotation system is constantly monitored on two displays - one for electricity consumption in kWh, and one for performance of solid material in t/h. During the tests was present the chief engineer of the equipment supplier "Gormasheksport" and designer of the flotation system Mr. Mikhail Yakovlev

2C. Material for grinding:The milling material is lead-zinc ore mined from the underground mine "Dimov Dol" near RUDOZEM. RUDOZEM is located in the southern part of Rhodope Mountains, Bulgaria. The ore has a lead content of 7% and contains up to 65% quartzite, i.e. it has a class of hardness 7 under the Mohs scale, extremely hard and abrasive. Ore falls into the mills chipped to a maximum of 25-30 mm. Grinding is preformed by the wet method.

2D. Grinding bodies: For milling of the ore are used grinding bodies of spherical shape and diameter of 60 mm, as the mills are charged with 6 to 8 t bodies, which determines that filling of the mills is not less than 45-50 %. In this case were used stamped by rails grinding spherical bodies produced by a company in Poland.

Fig. 1: View of the two mills, M1 (top) and M2.

Each mill is driven by an electric motor with an output of 75 kW. For grinding the ore, before the tests with the energy saving bodies, were used only spherical grinding bodies with 60 mm in diameter and average unit mass of 0,961 kg. . The spherical grinding bodies used during the industrial tests were produced by hot stamping from old rails by a company in Poland. The surface hardness of these spherical bodies was HRC 58-60.

Taking into account the type of ore and its particles' size we selected the innovative product model "Reloe-M1.1" as the most suitable for its grinding. Fig. 2. This model of grinding body has 4 parts of a sphere with a radius of 64,5 mm while the radius of the sphere of the spherical body is 30 mm. The surface of the "Reloe-M1.1" is about 9% bigger than the surface area of a sphere having a diameter of 60 mm. Furthermore, the innovative body has 12 edges.

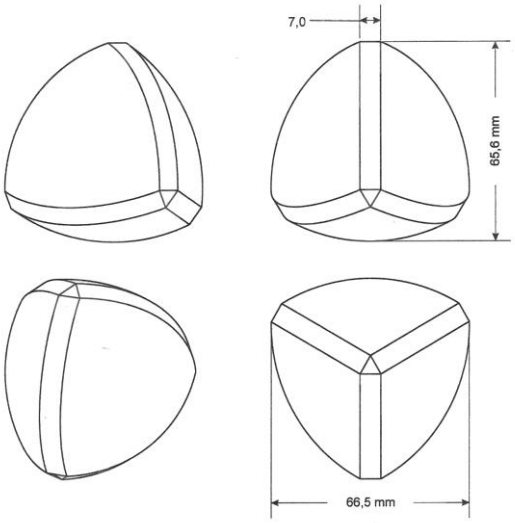

Fig. 2: Stereometrical image and size of "Reloe-M1.1"

The presence of this large number of edges provides increased capabilities of the body to shred the ore particles. The angle of the edges is 120˚, which gives them high impact strength. In the innovative energy saving bodies we preserve the spherical surfaces and even increase them comparing to the surface of similar spherical bodies. According to the research of G. C. NORRIS [4] these are namely the spherical surfaces that mill in the most productive way. Unfortunately, the particles of materials that are milled in drum mills are with significantly larger sizes than the optimal sizes for grinding. For this reason, it's been already more than 150 years now that spherical bodies do unusual activity for them - first destroy the large particles and then mill them. Obviously, the drum mill, apart from being is a grinding machine is also a multihiting hammer machine with free percussion parts. It is unacceptable however, these parts to be spheres. Throughout all labor and industrial history of mankind, destruction of materials is being realized with strikers that have an edge, most often shaped like a wedge. Our innovative body has edges for more productive crushing of particles but it also has spherical surfaces and they are multiple in order to perform the grinding. We believe that by offering these innovative grinding bodies we fully satisfy the needs of grinding of materials in line with technologies used today. In order for the ongoing industrial comparative tests to be more accurate our company "Reloe B" Ltd. produced 11 t of innovative energy saving bodies also from railway tracks, also by hot stamping and with the same surface hardness - HRC 58-60. The average mass of one innovative body is up to 1,011 kg. The preparations used from old rails for both grinding bodies, spherical and innovative, contain 0.8 to 1.3% manganese, (Mn) and 0.8 to 0.82% carbon (C). The steel used for railway tracks belongs to the cheap one and for its thermal treatment are used cheap technologies. In the case for hardening was used tap water and low temperature furnace for annealing after hardening. We found that the shape of the innovative bodies allows quality heat treatment while using cheap steel and cheap technologies for heat treatment compared to similar quality in spherical bodies. Previously we had also found that innovative bodies at the same volumes and masses as the spherical bodies occupy 10 % less volume by their respective spherical bodies. We believe that this greater compactness of the innovative bodies which allows in one and the same volume to accommodate up to 10% more grinding bodies than the number of analogous spherical bodies is another opportunity to increase productivity of drum mills. This opportunity will be investigated in subsequent tests. For the tests one mill M1 was loaded with 8 t spherical grinding bodies and the other mill, M2, was loaded only with 7 t innovative bodies. Such charging with less amount of grinding bodies was important because the larger diameter of the spherical parts of the innovative units provide greater surface of contact with the walls of the mill. This led to raising the innovative bodies to greater height during the rotation of the mills than the height of the spherical bodies. The electric motor of the mill was loaded more and turned off. The problem was solved by placing less grinding bodies in mill M2. So tests were conducted with different loads of the two mills, as mill M2 was charged with 12.5 % less load than mill M1 and its filling was about 32%. Meanwhile mill M1 was charged with spherical bodies up to 45-50 %. Throughout the tests mill M2 with the innovative bodies, worked with smaller loads

grinding bodies than mill M1 - with spherical bodies. We assume that the kinetic energy of the flow of innovative bodies in the mill was bigger than that of the spherical bodies. Every 24 h in mill M1 were added 100 kg of spherical grinding bodies and in mill in M2 – for about 100 h of operation were added 120 kg innovative grinding bodies. The mills were spinning with 19,5 rpm and 2 displays were reporting the productivity in t/h and electrical consumption in kWh. For the purpose of testing we recorded with filming equipment the references on the display about productivity t/h. Filming was due to the very fast change of data on the display. After that the captured data were included in the computer and recorded at intervals of 5 s.

3. Results from the treatment of captured data:

3 surveys were conducted – after 50 h , after 206 h and after 444 h of operation. The consumption of electrical energy was recorded accordingly.

Table 2

Date	Mill	Productivity t/h	Electrical consumption	
			kWh	kWh/t
18.11.2016	M1(spheres)	3.44	54	15.68
18.11.2016	M2(Reloe)	6.86	60	8.75
29.11.2016	M1 + M2	11.46	114	9.95
29.11.2016	M1(spheres)	3.96	54	13.63
29.11.2016	M2(Reloe)	7.5	60	8.00
16.12.2016	M1 + M2)	12.15	100.25	9.74
16.12.2016	M1(spheres}	4.35	51.5	11.82
16.12.2016	M2(Reloe)	7.8	48.75	6.25

Fig. 3 shows graphs of changes in productivity t/h during operation of the two mills together and independently of mill M1 and M2.

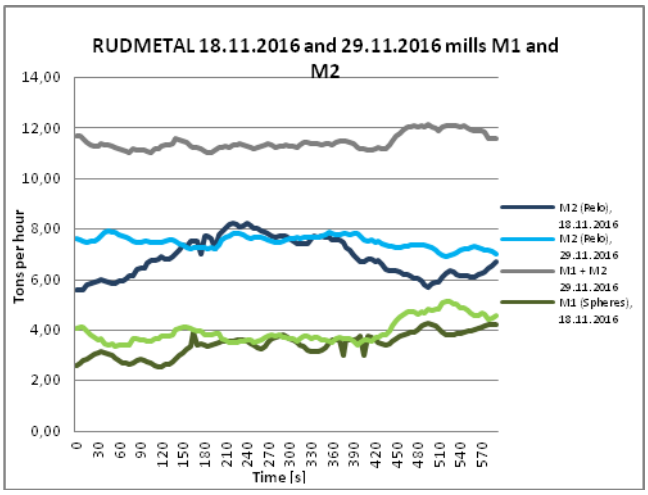

Fig. 3: Graphs modification of performance and electricity consumption both types of grinding bodies

Sieve analyses of the pulp, going out after the classifier, showed that the productivity of the estimated scale minus 0,075 mm of the mill M2 loaded with the innovative grinding bodies is 9.63% higher than that of the mill loaded with spherical bodies.

After 206 hours of operation of M2 the mill loaded with energy-saving grinding bodies " one of the two lids was opened and the following was found:

- increased wear out on the inside of the shell of the mill M2 with energy saving grinding bodies was not observed;

- the innovative grinding bodies wear out evenly and retain their basic shape.

Fig. 4 shows the innovative bodies in the mill.

Fig. 4: Energy saving grinding bodies in the mill after 206 hours of operation.

After 206 hours of working in extremely abrasive environments they have doubled their rounded edges and the new body then has only six rounded edges. Since the average weight of the worn out grinding bodies is already 0,880 kg, which means that the reduction of the mass of these bodies is on average by 0,131 kg. The decrease in size of the tops and spherical sides is in the range of 2-3 mm. The double edges have already fulfilled their purpose by destroying the material when the bodies had had an initial mass of 1,011 kg and then, with the rounded edges, the new bodies were fully involved in the milling of the ore. Measurement of the mass of separate worn out grinding bodies showed deviation of their mass by no more than 5 %.

This acceptable deviation and their symmetrical shape proved that energy saving grinding bodies participated in the milling with all their parts and therefore they obtained this uniform wear out and long-term retention of their shape.

Similar observation was conducted also after 444 hours of operation. It was approved that the grinding bodies retain their shape, obtained after 206 hours of operation and after 444 hours of operation.

Fig. 5 shows samples of the energy saving grinding bodies model “Reloe – M1.1” before the milling and samples after 206 and 444 hours of operation.

An important result is also the confirmation of the fact that the service personnel do not need additional training in order to operate with the innovative grinding bodies.

4. Conclusions

For the first time in the global mining practice were conducted industrial tests with innovative grinding bodies shaped in a similar way with that of spheroidal tetrahedron. The results from the conducted industrial tests for grinding with the innovative grinding bodies showed undoubtedly the advantages of the innovative grinding bodies compared to the spherical grinding bodies. They also proved that change in the shape of the grinding bodies is one of the ways to increase productivity and reduce energy costs for grinding. We believe that this opportunity has been neglected for many years and mining companies have limited themselves to the exclusive use of spherical grinding bodies improperly.

Except for increase in productivity by more than 90% the innovative grinding bodies reduce the cost of energy consumption by more than 40%. This gives us grounds to define the innovative bodies also like energy saving ones. The high rates of increase in productivity and energy savings can be explained only by a radical change and improvement in terms of crushing and grinding with energy saving bodies in comparison with spherical bodies. The tested innovative bodies appear as unquestioned alternative to the spherical bodies in the milling of materials. Given the huge scale of the mining industry, we expect the introduction of

innovative energy-saving bodies to have a significant effect in reduction of carbon emissions.

An important result is the finding that the innovative bodies do not cause increased wear out of the liner of the mills and retain for a long-term their shape and ability to work. Maintaining the shape of the innovative bodies after continuous operation means that there is an effect of self-renewal of the shape of the bodies.

We have been unable, so far, to explore the possibilities of obtaining even better results by using the bigger compactness of the innovative bodies. We believe that the possibility in one and the same volume to accommodate up to 10% more operating grinding bodies compared to spherical bodies is another opportunity to improve the technology fro grinding materials.

From a technological point of view we proved that quality innovative energy saving grinding bodies can be produced from cheap steel and using cheaper technologies for their production. We also found in our own production of 11 t innovative bodies that the existing technologies for mass production of grinding bodies such as casting, stamping and rolling can be used without technical and pricing issues for mass production of the energy saving bodies. Therefore, production of energy saving bodies does not require additional investments apart from the usual costs of tools.

We offer manufacturers of grinding bodies and their consumers faster mass introduction of the innovative energy-saving bodies in all cases of grinding materials with grinding bodies. We do not see any problems for production of ceramic grinding bodies with an innovative shape.

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5.References

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