RELO-B Ltd.

Forging machines • Rocket engines • Grinding bodies

Address: Bulgaria, 1504 Sofia, ul. Oborishte № 1 / A / 17
Address for correspondence: 1463.Sofiya Square. 1 "Bulgaria" on the back side of admin. building "Prono", 2nd floor.
Contact Person: Vassil Genchev +359888962989; +359 2 9166500; Fax. + 3592 9630606; e-mail: genchev@tu-sofia-bg.com, genchev@dedrax.com

INDUSTRIAL TEST OF ENERGY SAVING GRINDING BODIES

1. **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 grinding bodies (ESGB).

2. **Facilities for conducting the tests**: Two number drum mills MQG model 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.

Fig. 1: View of the two mills, M1 (top) and M2, model 1530 MQG.

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 "Gormashəksport" and designer of the flotation system Mr. Mikhail Yakovlev

3. Material for grinding: The milling material is lead-zinc ore mined from theunderground 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.

4. 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 with the data given in Table 1.

Table 1

Chemical composition				
Carbon C %	Manganese Mn %	Silicon Si %	Phosphorus P %	Sulfur S %
0.6-0.8	0.8-1.3	0.1-0.5	0.04	0.04
Bulk hardness HRC 53-54				
Surface hardness HRC 58-60				

Average mass of spherical bodies is 0,961 kg.

5. New grinding bodies: To test the new grinding bodies one of the mills, M2 was charged with energy saving grinding bodies with shape under the model "Reloe-M1.1" protected with industrial design in the EU: INTERNATIONAL REGISTRATION CERTIFICATE DM / 081 130/2013 1.-5 Grinding bodies, WIPO / HAGUE and in other 16 countries worldwide.

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

These bodies are also stamped by steel rail and have the following data listed in Table. 2.

Table 2

Chemical composition	
Carbon C %	Manganese Mn %
0.82	0.88
Surface hardness HRC 58-60	
Bulk hardness, HRC 56-58	

Average weight energy saving grinding bodies is 1,011 kg.

6. Terms for conducting the tests: One of the mills M1 was loaded with 8 t spherical bodies and every other day were added 100 kg of new bodies. The filling of the mill was about 45-50%. The other mill, M2, was loaded with 7 t energy saving grinding bodies Model "Reloe-M1.1" the filling of the mill was about 32%. Previously it had been found experimentally that the bodies "Reloe M1.1" occupy a volume of around 10% less than the volume occupied by the same number of spherical bodies. The loading only with 7 t energy saving grinding bodies was necessitated by the self-exclusion of the drive motor-driven, as a result of the less mobility of energy-saving grinding bodies in the early run of the mill. During the next 206 hours working in this mill were added only 240 kg new bodies. Both mills were working together with 19.5 rpm and the display reported the results of their joint work. Conditions in "Rudmetal" AD company allow only up to 120 hours of continuous operation of the mills. It stays 48 hours and starts a new 120-hour work cycle (5 working twenty-four hours a week). Breaks of this cycle are only in case of need to repair. For the purposes of the tests we conducted recording with photographic technique of the references on the display that show the productivity of dry matter in t / h. Filming was due to the very rapid change of reference of the instruments. The recording material was transferred to a computer and then was recorded at intervals of 5 s. Recorded were the references on the display during the work of both mills together and then during the work only of mill M2, which was loaded with new grinding bodies "Reloe-M1.1." The first recording took place on 18.11.2016, after 50 hours of operation of mill M2 with the new bodies. The second recording of data on the display took place on 11.29.2016, after 206 hours of operation of M2 mill with the new grinding bodies. The third recording of data took place on 16.12.2016 after 444 hours of operation of mill M2 and added 610 kg grinding bodies. During the same time were recorded the indications for electricity consumption.

7. Results from the treatment of captured data: Average results are given in Table. 3

Table 3

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 of solid work at 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.

8. Results from sieve analysis of the milled material: Sieve analyses were held on 17.11.2016 of the pulp going out from the neck and then from the classifier. For the pulp going out of the neck of the two mills, the sieve analysis showed that the productivity of the mill loaded with energy saving grinding bodies "Reloe" under the intended scale minus 0.075 mm is higher than that of the mill with the spherical balls with 3.16 %. For the pulp, going out after the classifier, the sieve analysis showed that the performance of the estimated scale minus 0,075 mm of the mill loaded with energy-saving grinding bodies "Reloe" after classification of the milled ore is 9.63% higher than that of the mill loaded with ball bodies.

9. Status of energy-saving grinding bodies after 206 hours of operation: After 206 hours of operation of the mill loaded with energy-saving grinding bodies "Reloe-M1.1," it was stopped and one of the two lids was opened. Figure 4 shows the view of the new bodies in the mill. It is seen that these bodies have retained their shape, which is close to that of spheroid tetrahedron. 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 units 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. By now they dominated by relative size, but we expect, over time, the mill with energy-saving grinding bodies to be filled with objects of different sizes and therefore further enhance their productivity. The consumption of grinding bodies is 0.640 kg / t of product.

After 444 hours of operation, grinding bodies retain their shape, obtained after 206 hours of operation, as the reduction of the external dimensions is about 6 - 7mm. The consumption of grinding bodies after 444 hours of operation is 0,61kg / t of product.

Fig. 5 shows the samples of energy saving grinding bodies model "Reloe – M1.1" before their taking part in milling and similar after 206 and 444 hours of operation.

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

0 h 206 h 444 h

Fig. 5: Model of energy-saving grinding bodies Model "Reloe-M1.1" before taking part in milling and a model after 206 and 444 hours of operation.

Based on mathematical modeling it can be assumed that in case of well-chosen technology of heat treatment and material, energy saving grinding bodies can operate until reaching size of 30 mm for about 100 days.

10. State of the lining of the mill, which was loaded with energy-saving grinding bodies: After 206 and 444 hours of operation one of the two lids of the mill was opened, and the mill was loaded with new grinding bodies. After the visual inspection it was not found out increased wear out of the lining of the lid of the mill and the lining of the mill liner itself. The cover of the mill has the same shape and material lining, what the mill has itself. In Fig. 6 shows a lid of the mill which was charged with energy saving grinding bodies, before and after opening.

а). б).

Fig. 6: rectangular lid of the closed mill b) rectangular lid of the the open mill, which was loaded with energy-saving grinding bodies.

Summarized data of the tests are given in Table 4.

Table 4

A comparative table of the results of industrial tests on the work of drum mills						
type MQG 1530 with spherical grinding bodies and grinding with energysaving bodies type RELO M 1.1						
	Mill M1,spherical grinding bodies Dy 60 mm			Mill M2, energysaving bodie with Dy 60 mm		
	composition in %: C- 0.6-0.8: Mn 0.8-1.3			composition in %: C- 0.82: Mn 0.88		
Dates for taking samples	18.11.2016	29.11.2016	19.12.2016	18.11.2016	29.11.2016	19.12.2016
1. Material for milling	lead-zink ore from Mine "Dimov dom"in town of Rudozem,up to 7 % lead, 65% quartsits, hardness by Moos 7, braked up to max. макс. 25-30 mm					
2. Amount of milling bodies,kg	8000	8350	9250	7000	7240	7840
3.Filling the mill, %	45-50	45-50	45-50	32	32	32
4.Surface hardness of the bodies by HRC	58-60	58-60	58-60	58-60	50-60	58-60
5. Volume hardnes by HRC	53-54	53-54	53-54	56-58	56-58	56-58
6. Heat treatment of the grinding bodies						
6.1 Harden	Yes	Yes	Yes	Yes	Yes	Yes
6.2 Alotment, 70 min	No	No	No	Yes	Yes	Yes
7.Average mass of one body, kg	0.96	0.810	0.65	1.011	0.88	0.748
8. Working houers, h	120	206	430	50	206	444
9. Average production in t/h	3.44	3.96	4.35	6.86	7.5	7.8
10.Estimated class - 0,075 mm, %	37.8	-	-	47,01	-	-
11. Power consumption, kWh/t	15.68	13.63	11.82	8.75	8.0	6.25
12. Wait lost of bodies ,kg/t of product	1.2	1.2	1.2	-	0.64	0.61
13. Status of the casing	no change	no change	no change	no change	no change	no change

11. Findings of the results from conducted industrial tests of energy-saving grinding bodies: The test results prove emphatically the advantages of energy-saving grinding bodies compared to the spherical grinding bodies. For similar volumes and masses of the two types of tested grinding bodies the significant difference in shape leads to a large increase in productivity and greater reduction in consumption of electric power - with over 40% per ton of production. Studies showed retention of form, which confirms our expectation for full participation of the entire outer surface in the grinding process. Based on the results we suggest a rapid implementation of energy-saving grinding bodies in the industry. Manufacturers of spherical grinding bodies will not have technological and cost problems with the introduction in the production of energy-saving grinding bodies. Users of energy-saving bodies will increase production without additional investments and reduce their energy costs.

12. Attachments:

- Sieve analysis of material from the neck of both mills.
- Sieve analysis of material from the classifier of the two mills.
- CERTIFICATE from SGS BULGARIA LTD.
- Film for production of the new grinding bodies and industrial tests with them: http://relogrindingbodies.com/

13. The test took place:

13.1. For "Relo B" OOD:

- Dr.-Eng. Peter Bodurov, Manager .....

- Eng. Vassil Genchev, Manager .....

13.2. For "Rudmetal" AD:

- Eng. Mitko Mladenov, Exec. Director .....

- Dr. Eng. Elijah Yochev, Ch. Mechanic .....

- Eng. Rosen Kyorov , Senior. Process man.....

13.3. For GORMASHEKSPORT " Russia:

- Eng. Mikhail Yakovlev, Ch. Engineer .....

13.4. For and on behalf of SGS BULGARIA LTD:

- Maryana Miladinowa Stoyanowa .....

Sieve analysis of samples from the mill neck

1.Mill with spherical bodies **pulp sample from outgoing neck 500 ml**

SAMPLE № 1

classes	yields		mul. (-)
мм.	гр.	%	%
+0.20	159	31,8	100
+0.10-0.20	131,7	26,34	68,2
+0.075-0.10	58,6	11,72	41,86
+0.045-0.075	58,3	11,66	30,14
-0,045	92,4	18,48	18,48
Total	500	100	

Hd = 73.07 %

SAMPLE № 2

classes	yields		mul. (-)
мм.	гр.	%	%
+0.20	162,1	32,42	100
+0.10-0.20	127,1	25,42	67,58
+0.075-0.10	61,3	12,26	42,16
+0.045-0,075	78,4	15,68	29,9
-0,045	71,1	14,22	14,22
Total	500	100	

Hd = 72.92 %

2.Mill with energy saving bodies ,, Reloe "

SAMPLE № 1

classes	yields		mul. (-)
мм.	гр.	%	%
+0.20	140,9	28,18	100
+0.10-0.20	136,9	27,38	71,82
+0.075-0.10	55,2	11,4	44,44
+0.045-0.075	90	18	33,04
-0,045	77	15,04	15,04
Total	500	100	

Hd = 68.96 %

SAMPLE № 2

classes	yields		mul (-)
mm	гр.	%	%
+0.20	137,7	27,54	100
+0.10-0.20	139,2	27,84	72,46
+0.075-0.10	56,5	11,3	44,62
+0.045-0.075	64,4	12,88	33,32
-0,045	102,2	20,44	20,44
Total	500	100	

Hd = 68.72 %

Conclusion : The performance of the mill with energy saving bodies "Reloe" by estimated class minus 0.075 mm is higher than the mill with spherical bodies with 3.16 %

The samples of M1 and M2 are made on 17.11.2016.

I. Mill № 1 (spherical bodies)

SAMPLE № 1

1. Contents of hard substance

Hd = 3.02/9.38 *100 = 32.19 %

2. Performance (dry wait)

3.02 kg for 4.59 sec

classes	yields		mul (-)
mm	гр.	%	%
+ 0.20	121.4	24.28	
0.1	143.1	28.62	
0.075	60.5	12.10	
-0.075	175	35	
Total	500	100	

SAMPLE № 2
2. Contents of hard substance

Hd = 3.28/10.70 *100 = 30.65 %

2. Performance (dry wait)

3.28 kg for 3.70 sec

classes	yields		mul (-)
mm	rp.	%	%
+ 0.20	93.90	18.78	
0.10	155.00	31.00	
0.075	52.30	10.46	
-0.075	198.80	39.76	
Total	500.00	100.00	

II. Mill № 2 (Reloe bodies)

SAMPLE № 1
1. Contents of hard substance

Hd = 3.22/11.04 *100 = 29.16 %

2. Performance (dry wait)

3.22 kg for 4.51 sec

classes	yields		mul (-)
mm	rp.	%	%
+ 0.20	73.4	14.68	
0.10	129.8	25.96	
0.075	57.3	11.46	
-0.075	239.5	47.9	
Total	500	100	

SAMPLE № 2

1. Contents of hard substance

Hd = 3.06/10.50 *100 = 29.14 %

2.Performance (dry wait)

3.06 kg for 3.73 sec

SAMPLE № 2

classes	yields		mul. (-)
mm	гр.	%	%
+ 0.20	44.8	8.96	
0.10	156.2	31.24	
0.075	68.4	13.68	
-0.075	230.6	46.12	
Total	500	100.00	

Conclusion: The performance of the Mill 2 with energy saving bodies " Reloe" by estimated class - 0,075mm after clacification of the milled ore is by 9,63% higher than this of mill M1 with spherical bodies.

In accordance with Client's instructions, the Company's involvement has been limited to witnessing/observing a third party's intervention(s) at the third party's laboratory/test house or other facilities and installations used for the intervention(s). The Company's sole responsibility was to be present at the time of the third party's intervention(s) to forward the results, or confirm the occurrence, of the intervention(s). The Company is not responsible for the condition or calibration of apparatus, instruments and measuring devices used, the analysis methods applied the qualifications, actions or omissions of the third party's personnel or the analysis results.
The SGS stamp and signature merely represents receipt of the document and SGS makes no representations as to the accuracy, adequacy and/or completeness of third party test/laboratory results, reports or certifications.

SGS
СЖС БЪЛГАРИЯ ЕООД
SGS BULGARIA LTD.