ГОДИШНИК НА МИННО-ГЕОЛОЖКИЯ УНИВЕРСИТЕТ "СВ. ИВАН РИЛСКИ", Том 54, Св. II, Добив и преработка на минерални суровини, 2011
ANNUAL OF THE UNIVERSITY OF MINING AND GEOLOGY "ST. IVAN RILSKI", Vol. 54, Part II, Mining and Mineral processing, 2011

IS THERE A MATERIAL CONSTANT WHICH CHARACTERISES MINERAL RESOURCES GRINDABILITY?

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ABSTRACT. This paper defines the grindability coefficient as the material constant that unambiguously characterizes the resistance of raw material to grinding. The grindability coefficient does not depend on the size of grinding product and in that way it facilitates the analytical consideration of the relationship between the used energy and grinding size.

ИМА ЛИ МАТЕРИАЛНА КОНСТАНТА, КОЯТО ДА ХАРАКТЕРИЗИРА СМИЛАЕМОСТТА НА МИНЕРАЛНИТЕ СУРОВИНИ?

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РЕЗЮМЕ. В тази статия се определя коефицинта на смилаемост, като материална константа и недвусмислено характеризира съпротивлението на суровината при смилане. Коефициентът смилаемост не зависи от размера на смилания продукт и по този начин улеснява аналитично разглеждане на връзката между използваната енергия и размерът на мелените частици.

Introduction

Among the three most mentioned comminution laws (Rittinger, 1867; Kick, 1885; and Bond, 1952), only Bond's law has a wide practical use (Bond, 1961):

$$W = W_i\left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}}\right) \qquad (1)$$

where:

W is specific energy consumption, in kWh/t;
W_i is Bond Work Index, in kWh/t;
P is square sieve opening passing 80 % of the product, in μm; and
F is square sieve opening passing 80 % of the feed, in μm.

According to the definition of F.C. Bond, the Work Index represents the energy which is required to grind one short ton of ore (1 sht = 907,18 kg) of unlimited large sizes ($F = \infty$) down to the size which passing of 80% through the sieve with square mesh size of 0.1 mm (P = 100 μm).

Bond's law has been widely used in practice because Bond had defined the laboratory test for determining Bond's Work Index which characterizes the resistance of raw material to grinding (defines the raw material grindability), which is not the case with similar parameters in the laws of Rittinger and Kick.

The only "disadvantage" of Bond's law of comminution is that Bond's Work Index W_i is not the material constant of raw material, but it varies with the change of grinding product size P. That is why Bond recommends that, in order to estimate the necessary energy for grinding, the Work Index W_i should be determined in the laboratory for grinding product size which is the same or very similar to the grinding product size of an industrial mill (Bond, 1961; Magdalinovic, 2003). This significantly complicates the use of Bond's law for analytical considerations of energy spending optimalisation in the process of mineral resources comminution. Comparison of raw materials according to grindability, stated by Bond's Work Index, is possible only if it is determined in a laboratory on all of the raw materials of the same grinding product size. N. Magdalinovic, in his research work, has pointed out in detail to this disadvantage and suggested a procedure for overcoming it (Magdalinovic, 1989a, 1989b, 1997, 2003; Ozkahraman, 2005).

The objective of the paper is to explore the possibility of a single parameter presence as a material constant which characterizes the raw material grindability, independent of the grinding product size P. In order to answer the question we have used the experimental results of the research of many years conducted by N. Magdalinovic on different raw materials as well as the latest research of the authors of this paper carried out on the copper ore within the project TR-33023 financed by the Ministry of Education and Science of the Republic of Serbia.

Experimental work

Standard Bond's test for determining work index W_i is done in laboratory Bond's ball mill which is used for determining the necessary parameters for calculating Bond's work index according to formula (Bond, 1961):

$$W_i = 1.1 \frac{44.5}{P_c^{0.23} G^{0.82} \left(\frac{10}{\sqrt{P}} - \frac{10}{\sqrt{F}} \right)} \qquad (2)$$

Where:

- P_c is mesh size of the test sieve, i in i µm;
- G is newly formed undersize per one mill revolution, in g/min.;
- P is mesh size passing 80 % of the undersize of the test sieve, from the last cycle, in µm; and
- F is mesh size passing 80 % of starting sample, in µm.

Table 1 shows the research results. The results clearly show that Bond's work index is not a material constant of raw material but varies with the change of mesh size P, i.e. with the change of mesh size of the test sieve P_c.

Table 1
Bond Work Index in ball mill at different sizes of grinding products

P_c	Copper ore			Andesite			Limestone		
	P	G	W_i	P	G	W_i	P	G	W_i
500	347	2.78	15.4	355	1.56	25.1	366	3.31	14.3
315	195	2.12	13.8	192	1.34	19.9	226	2.55	13.6
160	95	1.73	11.8	116	0.91	22.7	93	1.89	11.0
80	53	1.23	12.9	53	0.63	22.4	56	1.45	11.7
k	0.154			0.087			0.175		

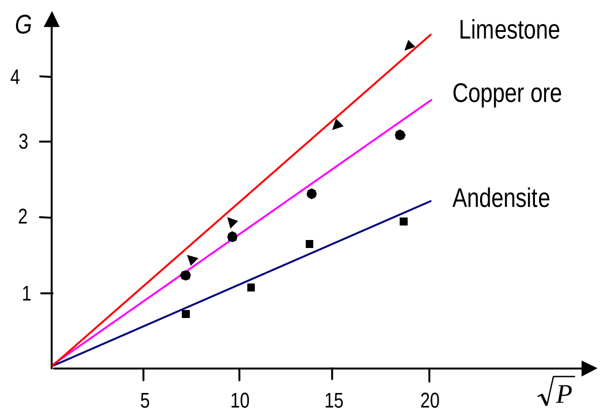

Fig. 1. Relationship G with P for laboratory Bond ball mill

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While looking for the answer to the posed question we will look at how the newly formed undersize per one mill revolution G changes with the change of undersize of the test sieve P. Graphic representation of this dependence is shown in Fig.1. Figure 1 shows that for all the raw material there is a strong correlation of the following form:

$$G = k\sqrt{P} \qquad (3)$$

The proportionality coefficient k in formula (3) represents the material constant for a specific raw material and we shall call it the grindability coefficient. It is independent of the undersize and unambiguously characterizes the resistance of the raw material to grinding. So, the answer to the question in the title of the paper is positive.

Acknowledgments

One part of the results used in this paper come from the work on project TR 33023 – the Development of technologies in the flotation processing of copper ore and precious metals with the aim of achieving better technological results, financed by the Ministry of education and science of the Republic of Serbia.

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