MINING AND METALLURGY INSTITUTE BOR
UDK: 622
ISSN: 2334-8836 (Štampano izdanje)
ISSN: 2406-1395 (Online)

UDK: 622.73(045)=111
doi:10.5937/MMEB1602047P

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CHECKING THE FORMULATION MODELING PROCESS OF INDUSTRIAL MILL FOR DIFFERENT TYPES OF GRINDING BODIES**

Abstract

This paper presents checking the formulation modeling process of industrial mill for different types of grinding bodies. It is known that changing the type of drilling bodies realizes various efficiency of grinding the mineral raw materials and/or different grinding fineness. This paper gives a hypothesis on bulk mass (density) of a mill batch as an influential factor to the size of specific grinding capacity of the specific mineral resources. The experiment was carried out in the industrial conditions of grinding when the Damkohler's criteria $D_{a_{q-d}} = \frac{q_{-d}}{n \cdot \rho_{\check{S}}}$ *was calculated [1]. Verification of this formulation was done in the industrial conditions, and testing results are present in this paper.*

Keywords: *specific capacity, bulk density, Damkohler's criteria*

INTRODUCTION

Production of water glass requires to have a high quality raw material (Fe_2O_3 <0.03%) and specific granularity. Particle size distribution of raw materials affects the energy consumption in the production of water glass, and is the optimal requirements sized quartz sand class -0,40 mm + 0.05 mm. Quartz sand from the deposit Bijela stena is mined and prepared for production of water glass in the site Lukic Polje near Milici up to 2014, when the company took over the entire site Kesogradnja and moved it to the location Kozluk, near Zvornik, in order to execute the adaptation of technology. The new facility has built a high gradient electromagnet for satisfactory chemical quality and the type of grinding body was changed to achieve finer grinding process.

THEORY

Buckingham's π Theorem

According to the Buckingham π theorem, every equations containing n_i does not relate to physical quantities (υ, where υ = nd, ρ, D, r .., etc.), among which m_i values have independent dimensions of size (M, L, t), can be transferred into equation which has n_i to m_i of dimensionless criteria and simplex, composed of these parameters

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** *The present results are a part of research within the Projects TR 34006 and TR34013, funded by the Ministry of Education, Science and Technological Development of the Republic of Serbia.*

[2,3]. This theorem is of great importance in the experimental and theoretical work. Dimensionless numbers are met practically for solving any problems in chemical engineering. Formation of dimensionless numbers for a particular problem is most easily achieved using dimensional matrixes [3]. Generally speaking, in the area of application, the chemical reactions with transfer of a power impulse and heat are used by Damkohler I (D_{aI}). The modified Damkohler [1] represents the equation of modeling the specific capacity of the mill q_{-d} .

$$D_{a_{q-d}} = \frac{q_{-d}}{n \cdot \rho_s} \tag{1}$$

Where:

q_{-d} - specific capacity of the mill to the newlyformed $-d$ calculated size class $ML^{-3}t^{-1}$,

d - side of square mesh openings in µm

n - number of revolutions of the mill per unit of time t^{-1},

$\rho_{\check{S}}$ - batch density ML^{-3},

Bulk Density of Batch of the Mill

Bulk density of batch is a size that mostly depends from the bulk density of grinding bodies and less than the pulp density. Bulk density of batch in the mill is calculated according to the formula [2] 3 and denoted by $\rho_{\check{S}}$:

$$\rho_{\check{S}} = \rho_{vk} + 1{,}15 \cdot (1 - \frac{\rho_{vk}}{\rho_{sk}}) \cdot \rho_p , \frac{kg}{m^3} \tag{2}$$

Wherein:

ρ_{vk} - bulk weight or density of balls in bulk density, in kg/m^3

ρ_{sk} - density of ball material from which was ball created or volume mass of balls, in kg/m^3

ρ_p - pulp density, kg/m^3

Bulk density of batch of the mill is the sum of the bulk density of balls bulk density, bulk density of material and density of water, which is located in the gap between the balls. Number of 1.15 in Equation 2 means that the empty space between the balls, which is filled with material which needs to be increased by 15% to make the balls, could perform the work of raw material and not to self-touch in the process of rotation of batch. The term in parentheses, Equation 2, is the empty space between the balls and it changes so that the different types of balls have different values: steel (0.46), pressed Al_2O_3 (0.44), and silicate (0.27). A large difference can be seen for empty space between the steel and silicate balls, as well as the pressed and silicate balls as expected because the steel and pressed balls are of spherical shape and a gap between the balls is larger; while the silicate balls are created in nature and have, in the least number of cases, a spherical shape, and a gap between them is smaller. The formula for the apparent density batch or bulk weight of the total charge of the mill, the first summand has over 80% influence on the bulk weight of the batch $\rho_{\check{S}}$.

Change the type of drilling body has therefore a major influence on batch density. A change of type the drilling bodies is rarely applied in the industrial mills because this kind of change is very expensive. In one mill, if it is permitted by motor power, with a change in type of drilling body, a specific grinding capacity is also changed. Water in the wet grinding process has a transport character due to its high viscosity. Water provides a particular lower pulp viscosity ranging from the input to output sleeve until balls rotate in the shell of the mill and do not move together with the pulp. Pulp density should be as much due to the efficiency of the grinding material in the mill. Pulp density in changing the bulk density of balls in the mill as a result of changes in species milling body does not remain the same already has a new value in order to ensure adequate grinding efficiency. For smaller bulk density of balls ρ_{vk} pulp density ρ_p is lower, and the higher the bulk density is higher. In a particular bulk mass of balls ρ_{vk} in the mill and pulp density ρ_p may remain constant when changing the capacity of the mill. These statements relate to more open regime of grinding and discharging of mill through the sleeve. The technological tests milling can be held constant density of a batch $\rho_{Š}$ to change the time of milling capacity.

Specific Capacity of the Mill

Specific capacity of the mill for the open grinding regime according to Magdalinović [4] is:

$$q_{-d} = \frac{M}{V \cdot t} \cdot \left(\beta_{-d} - \alpha_{-d}\right)\left[\frac{kg}{m^3 \cdot s}\right] \quad (3)$$

Wherein:

q_{-d} - specific capacity of the mill to the newly calculated size class

$-d$ at $kgm^{-3}s^{-1}$ (*d* representing square mesh sieve)

M -material weight in the mill *kg*,

V - volume of the mill m^3,

t - grinding time s ,

α_{-d} i β_{-d} - content of calculated size class $-d$ in the entry and grinding product in the unit parts

From the formulas for specific capacity, it can be seen that it depends on technological and design parameters. Constructive parameter is the mill volume (V), and the mass of material in the mill (M). The mass of material in the mill is a type of constant because the size means filling the empty space between the balls and very little changes with the capacity of mill. Technological parameter is the content of calculated size class $_{-d}$ in input and product of milling and is located to the formulation of specific capacity. To change the technological parameters of the mill is necessary to carry out the experiments changing hour capacity and output testing sized milling products. Then, the share of size class *-d* has to be determined in the product of grinding and feed grade. The specific capacity of the mill has a different value if there are different modes, open or closed regime. In open mode, the mill has a lower specific power while in the closed mode, he becomes hig-her for the same output plumpness milling products. The specific capacity of milling in the open mode, the mill can be easily changed by increasing or reducing the residence time of material in the mill. Changing specific grinding capacity in the closed mode, the mill is much more demanding, almost impossible, because then changes the amount of material that is returned to the mill, it is necessary to change the classification of devices. It should be noted that the process of grinding in a closed regime is more effective, however, the specific milling capacity increases relative to the open operation of the mill [5,6,7].

MATERIALS AND METHODS

In the open mode, the process of wet grinding sand from the deposit "Bijela stena", in operation Lukic Polje near Milici during the running section of the grinding silex balls varied the time of milling capacity to perform modeling of formulating the operation of industrial mill. In the procedure of the technological tests the pulp density was kept constant, and thus the density of the batch $\rho_{\check{S}}$. The paper [1] presents the results of modeling when dimensionless number of the "modified Damkohler" $D_{a\,q-d}$ was established.

Table 1 *Values of criteria* D_a *for different specific capacities* q_{-d}

Measured hourly capacity $Q\left[\frac{t}{h}\right]$,	Specific grinding capacity $q_{-d}\ \frac{kg}{m^3 \cdot s}$	Charge density mill $\rho_s\left[\frac{kg}{m^3}\right]$	r.p.m of mill $n\left[s^{-1}\right]$,	Value of Damkohler criterion $D_a = \frac{q_{-d}}{n \cdot \rho_{up}}$
4	0.084	2198	0.3	$D_a = \frac{q_{-200}}{n \cdot \rho_{up}} \cong 0{,}000127$
10	0.194	2198	0.3	$D_a = \frac{q_{-600}}{n \cdot \rho_{up}} \cong 0{,}000295$
15	0.272	2198	0.3	$D_a = \frac{q_{-830}}{n \cdot \rho_{up}} \cong 0{,}000413$

Dimensionless number $D_{a\,q-d}$, is a formulation that is a linear model function of the specific capacity of the mill, Figure 1, for different output because the fineness: density batch and a constant number of revolutions, Table 1 in column 3 and 4. If the apparent density of the batch mill is increased, then a new linear relationship

$$D_{a\,q-d_i} = \mathrm{f}\,(q_{-d_i})$$

is obtained, Figure 2 a straight line 2 and 3. The new linear relationship can be obtained by computation if known $D_{a\,q-d}$, Table 1 column 5. Calculation of determining the specific capacity of the new grinding q_{-d} for a new batch density $\rho_{\check{S}}$ is obtained by simply rearranging the equation 1. All is needed to do is to calculate the new specific milling capacity for the new density batch mill. During this operation it is necessary to know that at a higher bulk density of the balls can be used higher density pulp, which is defined by empirical equations for the design of mills. Linear dependence

$$D_{a\,q-d_i} = \mathrm{f}(q_{-d_i})$$

can be used for reading interpolation specific capacity of a size class for which is not experimentally determined specific capacities and is located between the minimum and maximum specific capacity, which is the work done. The same mill that is used Lukic Polje grinding by silex balls in Kozluk has more capacity for the same specific milling capacity q_{-d} because it uses steel balls. Also mill with steel balls can have the same time as the mill capacity to sileks balls or for two different sizes of output two different values q_{-d}.

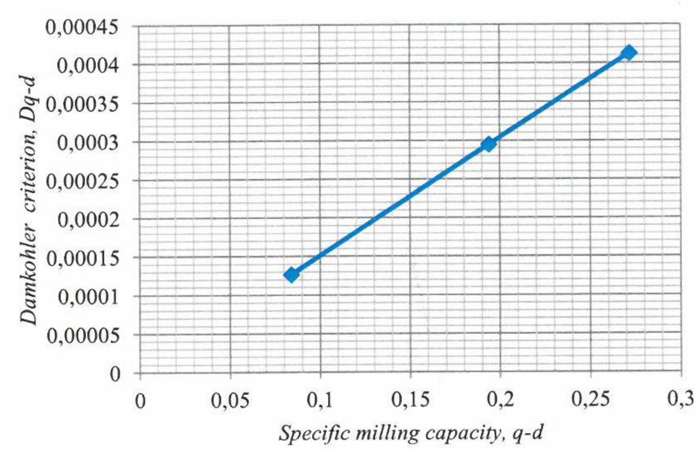

Figure 1 *Dimensionless criterion "Damkohler" in operation with specific capacity of the mill* $\rho_s = 2198\left[\frac{kg}{m^3}\right]$

RESULTS AND DISCUSSION OF RESULTS

Checking formulation modeling industrial mill will be carried out by the industrial conditions of the mill capacity to record time and determine the specific capacity for a new milling bulk weight of the batch mill with steel balls (law 3) in Figure 1. Figure 2 shows the three straight lines depicting three different the bulk density of the batch mill, and in line with different specific milling capacity when Damkohler criterion remains the function of the specific grinding capacity $q_{-d\ i}$. Analyzing the equation 1, it can be seen that for one and the same mill, the rule is that if it is required to increase the specific capacity of a certain size class, it is needed to increase the density of the batch mill. This idea in practice is rarely applied because the devices are designed for a specific technological scheme, so the adaptation is very unpopular. In the paper, "Modeling of the Mill to the Mill Batch Density and Specific Capacity" [1], an adaptation of a used mill with rods in the mill with silex balls was done in considering the engine power and the fact that in operation in an open-cycle the capacities can be changed. Then, experimentally are defined dimensionless criteria Damkohler for various specific milling capacity and density for the same batch. This dimensionless criterion is also appllied to the amended density batch mill, now a steel milling body when giving the new values of 0 specific grinding capacity, and thus predictable capacity mill in new technological circumstances. After downloading and installing the same equipment at the site Kozluk made the running plants with altered operating parameters section mills. This is based on the running and actual operating parameters led to the following results. The plant for grinding quartz raw materials in Kozluk is designed to work with the following operating characteristics [8]: the capacity of the mill is q = 10 th^{-1}, while size is 90% - 400 μm. Power output of the mill is N = 280, and the volume of the mill is V = V = 13 m^3. The mass of steel milling bodies in the mill is 18,000 kg. Speed mill is 17.8 o/min. The mill is discharged through the sleeve, and the density of the pulp at the outlet is 1,879 kg/l which means it has 76% of a firm in the pulp, (S:L then 1: 0.7). The mass of material in the mill is 2.34 t. During the milling is 10 minutes, the value of the Bond work index of quartz sand is 14.0 kWh/t. The apparent density batch mill in the industrial process of the mill in operation separation Kozluk was calculated according to the equation 2. Bulk density batch therefore has value $\rho_{\check{S}}$ = 5125 kgm^{-3}, Table 3. In order to find the specific capacity designed mill, the content of calculated size class was determined in the process input material, Figure 2, curve 1. At the optimum pulp density, it has been experimentally determined that the time capacity was 14 th^{-1}, Table 2. Then, it was obtained about 90% of class -400 μm in the final product, Figure 2, curve 2.

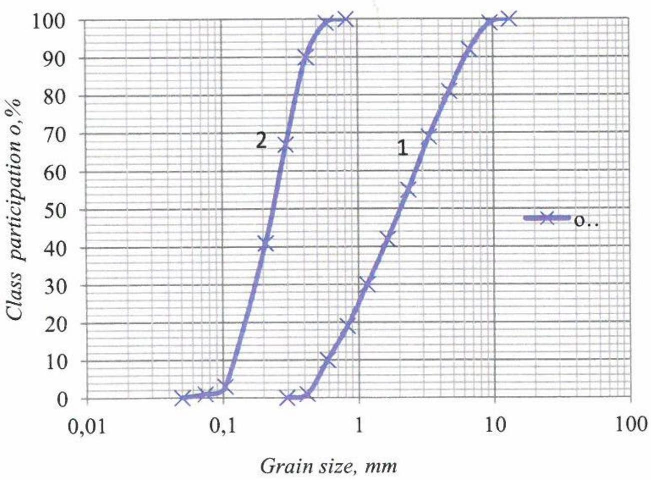

Figure 2 *Particle size distribution of the starting sample 1 and grinding product 2 at hourly grinding capacity of Q = 14 t / h*

The model was checked based on experimentally obtained values for the specific milling capacity in the site Kozluk and found that the point which defines the specific capacity of curve 3, applied to the density of the batch q_{-d} = 5125, Figure 3.

The same grinding mill in the same mode or with higher density batch gave higher capacity milling in comparison with the experiment, which was carried out with silex balls in the site Lukic Polje.

Table 2 *Experiment of kinetics in the industrial grinding mill with steel balls of the newly calculated size class –d*

Hourly capacity $Q\left[\frac{t}{h}\right]$,	**Grinding time** t $t=\frac{M}{Q}\cdot 3600[s]$	**Material mass in mill** ***m/kg***	**Mill volume V/m^3**	**The content of calculated size class in grinding product in inlet**		$q_{-d}=\frac{M}{V\cdot t}\cdot(\beta_{-d}-\alpha_{-d})\left[\frac{kg}{m^3\cdot s}\right]$
				β_{-d}	α_{-d}	
14	600	5125	13	0.90	1	q-400 = 0.27

Table 3 *Value of criteria* D_a *for the experimentally obtained capacity* q_{-d}

Calculated capacity $Q\left[\frac{t}{h}\right]$,	$q_{-d}\ \frac{kg}{m^3 \cdot s}$ **according to Magdalinović with metal balls**	**Total charge density** $\rho_{up}\left[\frac{kg}{m^3}\right]$	**r.p.m of mill** $n\left[s^{-1}\right]$,	$D_{aIM} = \frac{q_{-d}}{n \cdot \rho_{up}}$
14	0.27	5125	0.3	$D_{aIM} = \frac{q_{-400}}{n \cdot \rho_{up}} \cong 0{,}000175$

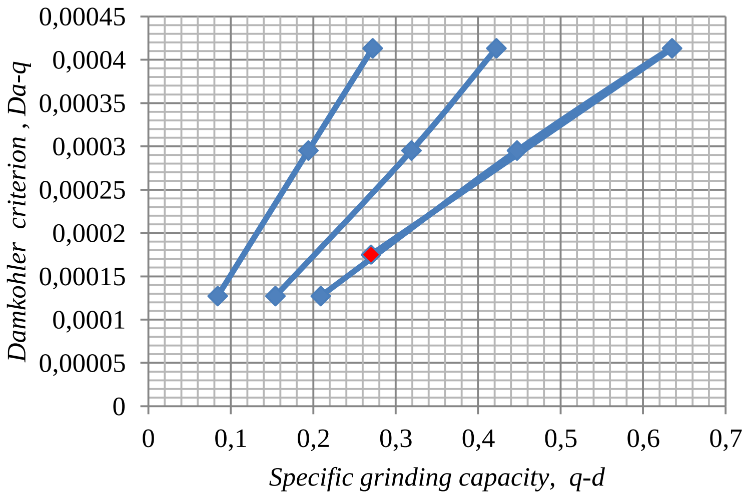

Figure 3 *Experimentally obtained points on the curve of dimensionless criteria "Damkohler" in function of the specific mill capacity. 1. silex balls; 2. alloy balls; 3. steel balls*

CONCLUSION

The aim of formulation modeling is predicting a new capacity of mill in terms of density variation drilling bodies in the mill batch. To be modified $D_{a_{q-d}}$ for a particular class of size remains the same as provided by dimensionless number, and if it is necessary to increase the bulk weight of the batch mill also increase the specific capacity of milling. Checking the modeling in industrial conditions was made after taking over the drive by the new investor, when it changed a type ofof balls, and instead silex balls are now used the steel balls. Bulk density batch, which depending on the type of milling bodies and grinding efficiency, increases with the use of balls with higher density. In this study confirmed the hypothesis about the influence of density milling bodies in a specific batch mill grinding capacity. This change allows the adaptation of the mill plant to increase capacity of the mill time, or to increase the fineness of grinding capacity at the same hour. The variation of the specific capacity of the mill is carried out on the basis of the Damkohler criteria. A good fact on specific mill that is built into the drive separation of quartz sand in Kozluk, near Zvornik, and which have been tested, is that the mill motor can support higher density batch milling body, so that the realized tests can be implemented in practice.

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