Investigation of factors of explosive ore pretreatment intensification at open-pit mines

Yuriy Mets

D.Sc. in engineering, professor
Kryvyi Rih National University
Kryvyi Rih, Ukraine
e-mail: ktu@alba.dp.ua

Andriy Levitskyy

Engineer, Director General
"MI-Center", JSC
Kryvyi Rih, Ukraine
e-mail: levitskyyap-micentre@ukr.net

Abstract
Factors intensifying explosive ore pretreatment at open pit mines are investigated. Transfer function of a crusher is developed.
Key words: EXPLOSION, FAILURE MECHANISM, PIT BANK, ORE PRETREATMENT, CRUSHER

Introduction

Analysis of modern pictures of rock failure mechanism by explosion allows to determine the main directions of improvement of benched breakage of rocks. And it is reduced to ensuring the obtain of mined rock with the set parameters for further effective ore-dressing processing. In this regard there is a need in evaluation of current state of benched breakage and obtained results. Special attention thus should be paid on improvement of ore pretreatment and determination of transfer function of initial crusher, to the share of which falls from 40 to 60% of capital expenditure and up to 50% of operational costs along the cleaning circuit.

Characteristic feature of modern ore pretreatment is the drive to receiving not only necessary fineness of the extracted ores, but also their granulometric size composition for further processing in crushers and mills.

In works [1,2,3] the influence of specific consumption of explosives and new methods of detonation on improvement of quality of crushing, reduction of strength of ore weight and improvement due to the change of quality of ore pretreatment, indicators of the subsequent operations of ore-dressing processing is shown. So, the increase of specific consumption of explosives on the career of “InGOK” mining and processing works, for example, allowed to gain considerable economic effect at the subsequent stages of processing. Similar results are received at the Poltava mining and processing works [4,5,6].

A number of the fulfilled works is devoted to increase of efficiency of subsequent ore-dressing processing due to formation of the blasted out mined rock with set granulometric and strength properties and its subsequent processing in initial crushers [7,8,9].

Initial crushers, as a rule, are conical of KKD 1500/180 type, with development of cyclical-and-continuous method became the indispensable equipment of large open pits. At the same time, when studying their impact on blasted out rock there are essential gaps, though the importance of these probes is obvious.

Analysis of previous researches

The core of crushing process in a cone crusher is as follows: at eccentric rotation of inner cone when it approaches to a motionless male cone, it with a greater force squeezes the pieces (wedged between cones at the time of removal of surfaces of cones), therefore they collapse. Between cones there is constantly open crack with minimum width L_{min} (at the moment of cones rapprochement) and maximum width of L_{max} - at the moment of removal of cones surfaces. It is obvious that pieces which sizes are less than L_{min}, pass through a crusher almost without changes. Actually the pieces with size more than L_{min} $(+L_{min})$ are subjected to crushing. Here one feature of the process should be noted. Real pieces have three unequal sizes: L.I. Baron [1] showed that the ratio between length, width and thickness of pieces in the blasted out rock in the center makes 2:1, 4:1.

Work objective. Establishment of transfer functions of cone crushers.

Material and research results.

We took special measurements of more than 100 pieces of the blasted out mass. Measurements showed that in great bulk ore pieces are of the form close to ellipsoid of rotation - (oviform, generally up to 300 mm), or in the form of cut columns (pieces up to 100 mm by the maximum size).

Therefore, only two sizes - maximum and minimum were measured. Thus, for the pieces with minimum size more than 200 mm the average correlation (piece lengthening) is $a_{+200} = l_{max}/l_{min} = 2.04$; $a_{-200} = 1.55$. Considering that the average size of a crack of cone crusher is 200 mm, than the pieces up to 200 x 2.04= 400 mm in size can pass through such crack by the maximum size.

Thus, in the crusher KKD 1500/180 fractions +400 mm are subjected to crushing. Fractions -400 mm pass through the crusher without change. Thus, in the first approximation transfer function of crusher in general view will be described by the following equation

$$\gamma_{+aL\min} + \gamma_{-aL\min} = \gamma'_{-aL\min} \qquad (1)$$

or

$$\gamma_{+400} + \gamma_{-400} = \gamma'_{-400} \qquad (2)$$

where γ - fractional yield according to blasted out mass, γ' - fractional yield after the crusher.

Such transfer function is sufficient for determination, for example, of the necessary size of a crack limiting the sizes of pieces according to the set maximum size (for safety of conveyor rubber tape). But to determine the output of small bodies, pebble stone and fines, i.e. three classes of fineness after crusher according to granulometric size composition of the blasted out rock, more difficult model of function is required.

To simplify records we will call the minimum crack of a crusher

$L_{min} = L$ – is crack width, and a – is piece lengthening. Let $L_2<L_1<L$ .We are interested in fraction a(L÷L1), a(L1÷L2) - aL_2, their output after a crusher:

$$\gamma_a\ (L \div L_1),\ \gamma_a\ (L_1 \div L_2);\ \gamma_{-aL_2} \qquad (3)$$

In the blasted out mass there are the above-mentioned classes:

$$\gamma_a\ (L \div L_1),\ \gamma_a\ (L_1 \div L_2);\ \gamma_{-aL_2} \qquad (4)$$

They will pass through a crusher without changes. The class will turn into classes (3) with probabilities:

$$P_{a(L\div L1)};\ P_{a(L1\div L2)};\ P_{-aL2} \qquad (5)$$

Than

$$\begin{cases} \gamma'_{a(L_1\div L_2)} = \gamma_{a(L_1\div L_2)} + \gamma_{+aL}\cdot P_{a(L\div L_1)} \\ \gamma'_{a(L_1\div L_2)} = \gamma_{a(L_1\div L_2)} + \gamma_{+aL}\cdot P_{a(L_1\div L_2)} \\ \gamma'_{-aL_2} = \lambda_{-aL_2} + \gamma_{+aL}\cdot P_{-aL_2} \end{cases} \qquad (6)$$

This, more complex, transfer function of a crusher will give the chance to calculate differently the output of three classes of fineness of mills charge after crusher according to granulometric size composition of the blasted out mountain rock, fed into crusher. But for this purpose it is necessary to define probabilities.

It is obvious that it is possible to construct the model for number of fractions more and less than 3 similarly. For example, for the model, where the fraction -400 ÷100 and 100 mm is of great interest, transfer function of a crusher will look as follows:

$$\begin{cases} \gamma_{-400\div100} = \gamma_{-400\div100} + \gamma_{+400}\cdot P_{-400\div100} \\ \gamma_{-100} = \gamma_{-100} + \gamma_{+400}\cdot P_{-100} \end{cases} \qquad (7)$$

Models of transfer function (6) and (7) are simple for calculations. But their objectivity requires the proof. The matter is that the class of +400 mm (or + aL) is non-uniform. It consists of pieces of various fineness from 1500 to 400 mm. Therefore models (5 and 6) will be correct only if crushing gear of large pieces is reduced to successive breaking off of parts of almost identical size (peeling). In this case the probability of transition *P* won't depend on the initial sizes of piece, and the model will be correct in this form. If there is a cracking of pieces, in this case the picture becomes complicated and the class γ_{+400} should be divided into separate parts, for example γ_{+600} and $\gamma_{-600+400}$, and for each to define P_{+600} and $P_{-600+400}$.

Herein model (7) will look as follows:

$$\begin{cases} \gamma'_{-400+100} = \gamma_{-400+100} + \gamma_{+600} \cdot P_{-600+100} + \gamma_{-600+400} \cdot P_{-400+100} \\ \gamma'_{-100} = \gamma_{+600} \cdot P_{-100} + \gamma_{-600+400} \cdot P_{-100} \end{cases} \quad (8)$$

And in general terms

$$\begin{cases} \gamma'_{a(L_1 \div L_2)} = \gamma_{a(L_1 \div L_2)} + \gamma_{+A} \cdot P_{a(L_1 \div L_2)} + \gamma_{-A+B} \cdot P_{a(L \div L_1)} \\ \gamma'_{-aL_1} = \gamma_{-aL_1} + \gamma_{+A} \cdot P_{-aL_1} + \gamma_{-A+B} \cdot P_{-aL_1} \end{cases} \quad (9)$$

where A>B>aL.

These models differ from previous with the growth of number of members in the right part. For check of influence of the initial sizes of pieces on probabilities of transition of P laboratory experiments on laboratory jaw crusher 60/20 are made. For this purpose there were prepared 10 pieces of ore from a pit, with sizes +60 mm, 50 mm, 40 mm, 30 mm, 20 mm. These samples are shown in fig. 1.

The sizes of pieces are picked up so that 4 of them more than middle size of a crack and one is approximately equal to a crusher crack. Pieces of one size are loaded into a crusher. After crushing screening of crushed ore is carried out.

In order to extrapolate results of crushing in laboratory conditions on industrial, let us present the borders of fractions in relative units, having expressed them in crack size shares. For crusher 1500/200 the range of pieces size can be divided into the following fractions, mm: 1200÷600; 600÷400; 400÷200; 200÷100; 100÷50; <50, or in crack sizes: 6L÷3L; 3L÷2L; *2L÷L; L* ÷0,5L; *0,5L* ÷ 0,25L; <0,25L.

Fractions more than L are subjected to crushing and pass into fractions with the sizes < L. Thus, according to the results of experiment it is possible to estimate the probability of transition of large fractions into small bodies (2 – 0.5); pebble stone (0.5 – 0.25) and fines (0.25).

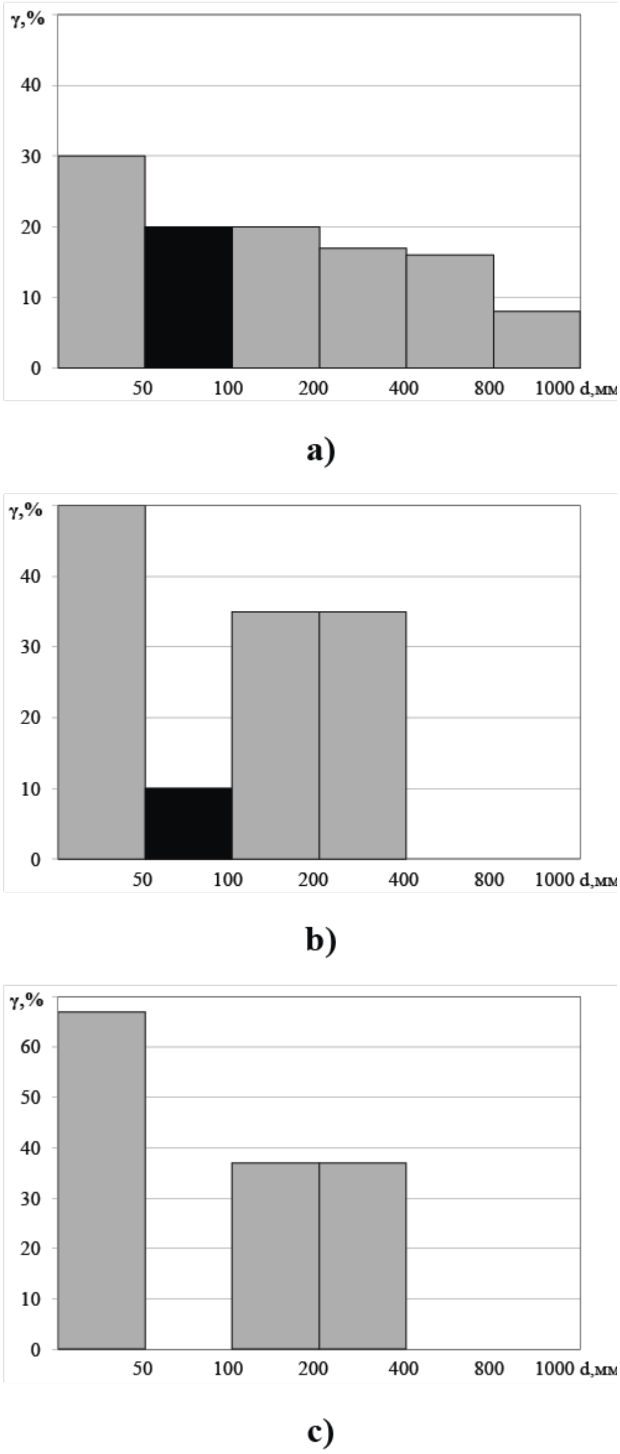

Figure 1. Histograms of particle size distribution of the blasted-out ore: *a* - actual; *b* - ideal for section with hollow self-crushing; *c* - for section with the combined self-crushing

The results of crushing are presented in the table 1. Transformed data (table 2) are presented in the table 3.

Analysis of table 1 shows that with approach of the sizes of large pieces in initial ore to the sizes of crusher crack, the probability of their transition to the grinding bodies increases and the probability of transition in pebble stone and fines decreases. In other words, to reduce the output of intermediate bodies, it

Table 1. Probability of transition of large fractions in others

Pieces size before crushing	Pieces size after crushing	
	7 pebble stone 10.5 – 0.25	8 fines 0.25
3L	$P_{17} = 0{,}18$	$P_{18} = 0{,}16$
2,5L	$P_{27} = 0{,}17$	$P_{28} = 0{,}18$
2L	$P_{37} = 0{,}20$	$P_{38} = 0{,}14$
1,5L	$P_{47} = 0{,}18$	$P_{48} = 0{,}12$
L	$P_{57} = 0{,}06$	$P_{58} = 0{,}06$

Table 2. Probability of change of pieces size after crushing

Pieces size before crushing	Pieces size after crushing		
	> 0.5L	0.5L ÷0.25L	< 0.25L
> 21	P_{13}=0.65	P_{14}=0.2	P_{15}=0.15
2L ÷ L	P_{23}=0.8	P_{24}=0.1	P_{13}=0.65

is necessary to reduce output of large classes in the blasted out mass. Such dependence is possible if to assume that the pieces of ore crack not at once into parts, but small pieces gradually break away from them, especially in the top zone of a crusher where the course of the splitting-up surface is small and the speed of loading is also small. It is also noticeable that within the range of *3L÷2L* the probabilities of transition do not really differ, whereupon the model can be simplified.

Of course, it is impossible to transfer the results of determination of probabilities on laboratory experiments to real cone crushers. Therefore for assessment of actual values of probabilities of transition for crusher KKD 1500/180 industrial experiments on the Annovsky open pit of "SevGOK" mining and processing works on the ores similar on strength to the oxidized ferruginous quartzite of "InGOK" mining and processing works were conducted. Granulometric composition in four mine breasts working for transfer group with KKD 1500/180 crusher is changed with this aim. Then, during several shifts, measurement of granulometric size composition in bodies of dump trucks at the time of rash into a crusher is carried out. Thus photoengraving of ore on conveyor hoister feeder was synchronously carried out. Measurements are performed in volume of 110 dump trucks, thus the transfer group accepted about 4 thousand tons of ore. At the time of measurements three mine breasts worked at ores of a lying pack southern and one mine breasts on ores of a trailing pack of northern part of a pit. Average data are provided in table 3.

Table 3. Change of granulometric composition of mined rock

Measuring point	Granulometric composition, %							
	+1200 mm	+1000 mm	+800 mm	+400 mm	+200 mm	+100 mm	- 400 +200	- 400 +100
In the mine breast	2.3	3.4	6.6	18	35	57	17	37,0
In the body of dump truck	2.1	3.1	6.0	7.5	34	55	16.5	36.5
On the feeder of conveyer CCM (KKD 1500/180)	-	-	-	2.3	17.5	38.5	17.2	36.2

The data provided in table 3 show that when loading in dump trucks granulometric size composition of the blasted out mass almost doesn't change. The output of a class of +100 mm on the conveyer belt made at averaged 35.8% that is almost correspond to an output of a class -400+100 mm in the blasted out and shipped ore. Thus it is stated that "generator" of grinding bodies in the blasted out ore of the Annovsky open pit is generally a class of -400 +100 mm. One should also pay attention that in the ore there is more than 3% of a class of +1000 mm, and more than 2% of oversize material, that is 20-30 times higher, than according to reported data.

Thus, for the simplified calculations it is possible to present that transfer function of crusher KKD 1500/180 looks as follows:

$$\begin{cases} \gamma'_{+100} = \gamma_{-400+100} \\ \gamma'_{-100+50} = 0.5\gamma_{+400} + \gamma_{-100+50} \\ \gamma'_{-50} = 0.5\gamma_{+400} + \gamma_{-50} \end{cases} \quad (10)$$

Investigations allow to provide optimum granulometric composition of the blasted out mine rock for which it is necessary to strive during ore breaking at the career. This granulometric size composition is presented in fig. 1 for the main scheme of self-crushing of ROF-2 with ore-pebble crushing in the II stage for which about 10-15% of ore pebble from the I stage of crushing is necessary.

There is no need in pebble for the scheme with spherical crushing in the II stage, therefore it is a ballast for the 1st stage of self-crushing, and it is necessary that its amount in the blasted out ore was as small as possible.

From the above mentioned, quite great amount of pebble is formed in a crusher of large fractions therefore a priority for breaking is reduction of output of class +400 mm in the blasted out ore. This task doesn't contradict the requirements of mining operations conducting, but also promotes their improvement.

Conclusions

1. Transfer function of cone crushers of large crushing according to granulometric composition is developed.

2. It is proved that "generator" of the grinding bodies in the blasted out ore of a pit is the output of a class -400 +100 mm.

3. It is established that pieces larger than 400 mm are processed by a crusher generally in a class -100 mm, and equally in pebble and fines.

4. To increase of productivity of process of self-crushing it is necessary to reduce an output of class +400 mm in the blasted out mine rock with simultaneous finishing of output of class - 400 +100 mm to the level 30 - 35%.

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