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Crusher Shifting Space Optimization in Horizontal Surface Mines

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Abstract. The reasonable crusher shifting space should ensure that the comprehensive production cost of the open pit is the lowest. Factors affecting crusher shifting space were analyzed and economic indexes, system links composing and disposal scheme were put forward dealing with semi-continuous system management. The study show that the reasonable shifting space must guarantee the crusher shifting costs compensated by saving the transportation costs. At the same time, the stope space restrict must be taken into consideration, to avoid the situation of advancing stripping and lagging in-dump caused by the best abilities of crusher disposal. Conclusions drawn from this research demonstrated that the lowest production cost should be the final target in the crusher shifting space project, while the shifting cost compensation and the slope space restriction are the boundary conditions, by which the optimized outcome can be confirmed synthetically. A Case study shows that the crusher shifting space determined by the multi-factor synthetically method is 180 meters farther than that confirmed by the traditional economic principles.

Introduction

Disposal and shifting of the crusher are core technical problems in semi-continuous mining system, while there are a lot of factors affecting the crusher shifting space. Take the truck-crusher-belt conveyor haulage system for example; the purpose of crusher shifting is to shorten the truck transporting distance and to decrease the haulage cost, value of the shifting distance directly influence the operation effect of semi-continuous system [1~3]. In a word, the crusher shifting optimization study is of crucial importance. Plenty of researches has been done concerning crusher shift distance, the majority of which was with the minimum production cost principle [4~11], while there were a lot of factors involved in such kind of research, current economic principles sometimes take into more consideration part of materials exploited in the semi-continuous mining system than the influence between the end-slope crusher layout and other mining systems. Based on flat surface mine model, the synthetically model was established considering the influence of mining system disposal and its space condition on crusher shifting space.

Surface Mine Model

The obliquity of flat surface ore body is less than 5 degree, so the crusher shifting form acts as a manner of plane shift. Semi-continuous mining system model in surface mine is demonstrated as in Fig.1, if the level elevation of the pit bottom is 0, the crusher is disposed at a certain height H on the end-slope in the stope (H is the relative highness between the crusher laid level and the pit bottom, with the value [0~H_{max}], and H_{max} is the relative highness between the ground surface and the pit bottom,), material barycenter height entering the semi-continuous system is h. In the working slope advancing direction, it is supposed that the material barycenter is the origin, the working slope positive direction and the in-dump negative; and length of working bench is L_0, the plane distance between the material barycenter and the crusher in the working slope advancing direction is L.

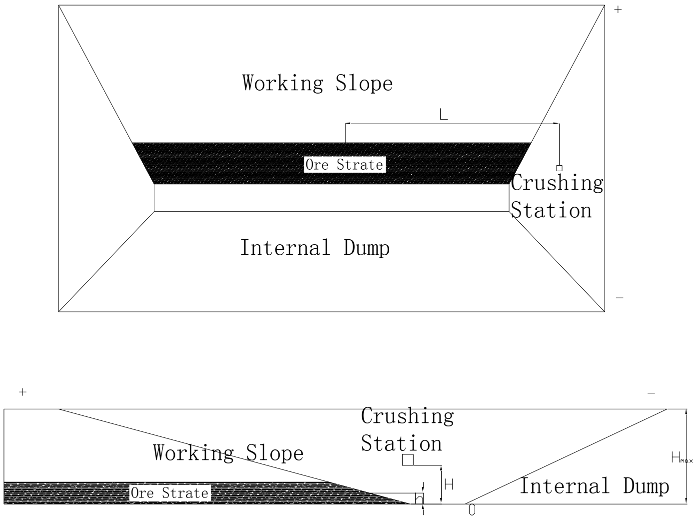

Fig. 1 semi-continuous mining system model in flat surface mines

Optimization Model of Crusher Shifting Distance

Economic Shifting Distance

Economic guide lines of crusher shifting space can be summarized into four main types [4]:

(1) Shifting Costs Compensation Method: this method requires that the shifting investment can be compensated by which saved in the ore and rock transportation process in the crusher shifting-served section.

(2) Minimum Unit Cost Method: in this theory, the crusher shifting costs and the production loss caused by crusher shifting are apportioned among the serviced sections, the final goal is that the unit ore and rock transportation cost keeps the minimum.

(3) Minimum Gross Cost Method: The gross ore and rock transportation cost served once in the crusher shifting procedure should keep least in this method. The calculation result keeps the same as what is mentioned in the Minimum Unit Cost Method.

(4) Expectation Compensation Method: The expected shifting cost compensation time is taken as the estimating standard after the crusher is shifted; the crusher is not suitable to be shifted if its service period is shorter than the expected compensation period.

Realization of the minimum production investment is the ultimate goal of surface mining optimization. Meantime, there are a good many factors affecting it. In addition, plenty of production links exist in semi-continuous system, which are hard to consider comprehensively, two factors are mainly considered in research ever did: the transportation costs and the crusher shifting investment. So in this study, the author held that the Minimum Cost Method can be considered more as a reference calculating crusher shifting distance than a gist.

In order to avoid increased production fee caused by frequent shifting of crusher, Shifting Costs Compensation Method and Expectation Compensation Method are adopted in this research, in other words, the crusher shifting space should meet the following in equation:

$$S_1 \geq \max(S_y, S_q) \tag{1}$$

In this equation: S —reasonable crusher shifting space, m; S_y —minimum shifting space confirmed by the Shifting Cost Compensation Method, m; S_q —minimum shifting space confirmed by the Expectation Compensation Method, m.

What is shown in this in equation is that the crusher-shifting cost is compensated from the former place to the current position as well as from the current place to the new position, by which the production increased cost will be avoided resulting from crusher shifting.

Transportation Highness Factor

Confined with the slope climbing ability of mining trucks, materials exploited from the working face are transported to the crusher stand level, the ramp length during this stage is:

$$S_p = \frac{H-h}{\sin\varphi} \tag{2}$$

In this equation: S_p —the ramp length climbed by the truck, m; H —the crusher standing level in the mining pit, m; h —the level of material barycenter entering the semi-continuous system, m; φ —the truck climbing grade, °.

As is demonstrated in the equation above, no matter how the crusher moves in the plane direction, truck transportation distance of materials will not be less than S_p as long as the crusher standing height is fixed. What is shown in Fig.2 is influence of end-slope conveying tunnel on truck transportation distance of material.

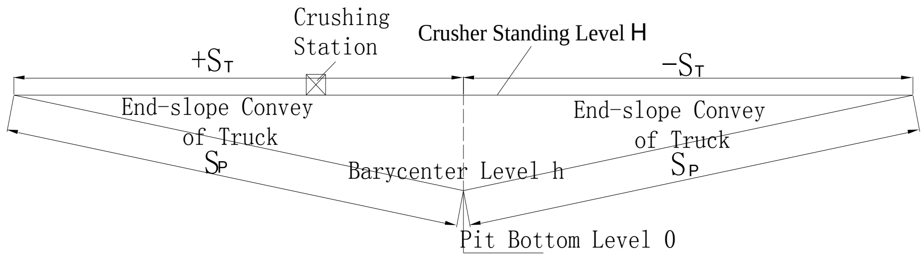

Fig. 2 Truck Transportation Channels Disposal

In this theory, the minimum plane disposal space required for truck transportation paths is:

$$S_T = S_p \cdot \cos\varphi = \frac{(H-h)\cos\varphi}{\sin\varphi} = (H-h)\cot\varphi \tag{3}$$

Under the condition of the surface mine developed by end-slope pits, the position of the crusher will not change, but the barycenter of materials will advanced from the "$-S_T$" position to the "$+S_T$" position. In this process, truck transportation distance of materials may hold the line by adjusting the truck running ramp, the minimum truck transportation distance is:

$$S_k = S_p + L \tag{4}$$

Supposing that the surface mine developed by working slope motional pits, minimum truck transportation distance of materials is:

$$S_k = \max\{S_p, \sqrt{L^2 + (H-h)^2}\} \tag{5}$$

Occasion 1: $L \geq S_T$, Materials may be transported by running trucks through straight working slope motional pits, the crusher shifting space is not influenced by the material re-transportation height in this case. The optimization shifting step gridding under the influence of transportation highness is: $S_2 = S_1$, reasonable truck transportation distance is: $S_k' = S_k + \frac{S_1}{2}$.

Occasion 2: $L < S_T$, no enough space around the working slope can be used to dispose straight pits, reentrant lines need to be arranged to meet the needs of moving pit lines, minimum truck transportation distance of materials S_k' is S_P at this moment, reasonable truck transportation distance is $S_k' = S_P + \frac{S_1}{2}$.

Occasion 3: For some surface mines whose mining depth is deep and working bench is short, in order to avoid returning conveyance of material, ramps development adopts end-slope pits combined with working slope temporary ramp, and part of end-slope is adopted as the material conveying passages. It is supposed that:

$$S_T' = S_T - L \tag{6}$$

Provided that the crusher position is fixed, the truck transportation distance will not change while the material barycenter is advanced from "$-S_T'$" position to "$+S_T'$" position. By above analyses we know that a certain space S_2 is required to dispose truck conveying ramp on the open-pit end-slope in order to overcome the conveying height. S_2 Must meet these conditions:

$$S_d = \begin{cases} 0 & \text{Working slopeRamps Development} \\ (H-h)\cot\varphi & \text{End-slope Ramps Development} \\ (H-h)\cot\varphi - L & \text{Other Ramps Developmen} \end{cases} \tag{7}$$

So the minimum reasonable shifting distance should obey $S_2 \geq 2S_d$ which is decided by the material transportation height.

Stope Space Factor

In order to shorten the in-dump transportation distance and speed up the mine reclamation engineering, in-dump should be carried out as soon as possible, so the space left for disposing crusher is quite limited. From the view of decreasing crusher disposal cost, such issues must be taken into consideration, for instance, advanced stripping and the in-dump developing disturbing.

As in Fig.1, without regarding advanced stripping, we take the material barycenter position as the 0 coordinate, and then the maximum advanced distance of the crusher which can be disposed is:

$$S_g = (H-h)\cot\alpha \tag{8}$$

Because the crusher position will not change in a certain service stage, and as the working wall is developing, Barycenter of the material exploited may exceed the crusher after a short period of time. On the assumption that the overburden in-dumping is not disturbed, the maximum lagging distance between the crusher and the material barycenter is:

$$S_n = A + h\cot\alpha + H\cot\beta \tag{9}$$

By analysis it is known that if there is neither advancing stripping nor in-dump transportation distance increasing. The maximum crusher shifting space S_3 is:

$$S_3 = S_g + S_n = (H-h)\cot\alpha + A + h\cot\alpha + H\cot\beta = A + H(\cot\alpha + \cot\alpha) \tag{10}$$

Synthetically Factor

For a certain open-pit mine, the two types of space condition restrictions are more interacting than isolated. In the production process, we do not want to waste the truck transportation space, which will bring on extra crusher shifting, nor do we want to lessen the crusher shifting, which will engender advanced stripping or lengthen the in-dump conveying distance.

In the working slope advancing direction, the maximum distance between the crusher standing position and the material barycenter is:

$$S_q = \min\{S_2, S_g\} \tag{11}$$

While the maximum lagging distance between the crusher and the material barycenter is:

$$S_h = \min\{S_2, S_n\} \tag{12}$$

So the reasonable crusher shifting distance confirmed by the technics system disposal and the stope space condition should meet the following equation:

$$S_4 = S_q + S_h = \min\{S_2, S_g\} + \min\{S_2, S_n\} \tag{13}$$

Considered all the factors, the crusher shifting distance should meet the following equation:

$$S \geq \max(S_1, S_4) \tag{14}$$

Case Study

A surface mine was exploited with the bottom level 140 m, the coal seam is embedded in flat manner with the average thickness 30 m, density of crude coal is 1.4t/m^3, the productivity of surface mine is 20 Mt/a and the working line length is 2000 m, the crusher is disposed on the ground level of the west end-slope. According to the datum of jobsite, the crusher shift distances calculated are listed in the following table 1.

Table 1 The crusher shift distances calculated by each method

Sequence number	Calculating principle	Main parameter	Results/m	Remark
1	Economical shifting distance	Shifting cost compensation method S_y	346	
2		Expectation compensation method S_q	323	
3		Economic shifting space S_1	346	$S \geq S_1$
4	Transportation highness factor	Transportation height requirement S_p	1563	
5		End-slope ramp requirement S_d	263	
6		Shifting space determined by the material transportation height S_2	526	$S \geq S_2$
7	Stope Space Factor	Maximum exceeding distance S_g	436	
8		Maximum lagging distance S_n	497	
9		Stope space S_3	933	$S \leq S_3$
10	Space integrate influence	Space synthetically influence S_4	526	$S \geq S_4$
11	Optimization shifting distance	Shifting distance of the end-slope crusher S	526	

Annotate: connection of optimization shifting distance and calculation shifting distance.

From the calculating results, it can be known that the most optimal crusher shifting space under the current situation is 526 meters, which is 180 meters farther than the value given by the traditional methods. The reason is that the surface mine adopts working slope temporary ramp and end slope semi-permanent ramp composite ramp system, the transportation distance of crude coal stay fixed with the crusher in the service range, which is affected by the transferring height.

Conclusions

Conclusions are drawn as follows:

(1) Plane shifting is the main crusher shifting mode in flat open-pit mines, shifting cost should be guaranteed to be compensated while selecting reasonable shifting distance, and it must be also

guaranteed that the shifting cost be compensated after shifting.

(2) While the materials are conveyed through the end-slope ramps, truck conveying distance of materials may keep constant in a extent by adjusting the end-slope ramp composition. The reasonable shifting space must meet the maximal possible adjustment extent of end-slope ramp.

(3) End-slope crusher disposal is confined by the stope space, when the height (H) between the crusher standing level and the pit bottom is a constant, in order to avoid unnecessary advanced stripping and in-dump lagging, the reasonable crusher shifting distance should be no farther than the available stope space under the normal mining advancing condition.

(4) For a determinate surface mine, the two types of space condition restrictions are more interacting than isolated and the minimum production investment should be ensured.

(5)The case study indicates that the optimization result may change remarkably if we take into consideration the influence of the technics system disposal and the pit space condition.

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