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Impact of Blast Fragmentation on Truck Shovel Fleet Performance

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ABSTRACT: This paper presents an outline of the work conducted to date at the Julius Kruttschnitt Mineral Research Center (JKMRC), Brisbane, Australia on the effect of blast fragmentation on truck shovel fleet performance. The project is an important component of the ongoing " Mine To Mill " project which looks at the optimisation of downstream processes after blasting. The results of numerical modelling studies and site work are presented.

1 INTRODUCTION

"Mine to Mill" is a comprehensive project initiated and developed at the Julius Krutschnitt Mineral Research Center of the University of Queensland, Brisbane, Australia. The project aims to optimise down stream processes in relation to blast fragmenattion. One of trie important component of the project is to determine the impact of blast fragmentation on truck shovel fleet performance. This paper summarises the work done to date on this issue.

In order to achieve the project objectives three large scale field trials were conducted. Three different blast designs were tested in the same rock domain. Performance of truck shovel fleet was monitored after each blast. The key performance indicators of the truck shovel performance were assessed in the light of fragmentation achieved.

2 DISPATCH DATA

Raw dispatch data were supplied by the sponsor mine site. The data included truck arrival times to the shovel and primary crusher, as well as the start and end of loading times over the period of testing. The data were sorted and analysed for individual loading times, full and empty return times and waiting times. Only the trucks with the Cat Weightometers installed have been assigned to the nominated shovel.

Breakdown of the dispatch data of the October trial is shown in Figure 1.

Empty haul (10.9 minutes), full haul (11.5 minutes) and dump time (7 minutes) take the biggest proportion of time.

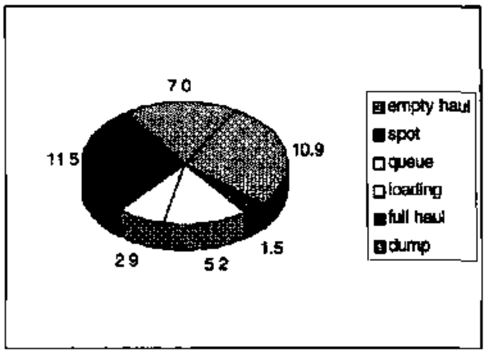

Figure 1 Break down of average cycle time in minutes (Dispatch records over 98 cycles, October 2000 data).

3 LOADING PERFORMANCE MEASUREMENTS

The individual dig times for each pass were measured from the recorded video tapes of the operation. The measured dig time distribution is shown in Figure 2. The average dig time is 12.2 seconds with a standard deviation of 1.75 seconds. Measured values ranged from 7.6 to 21 seconds. The May trial value was 18.8 seconds. This represents a 35 % improvement over the May trial average. The difference is statistically significant at 95 % confidence level.

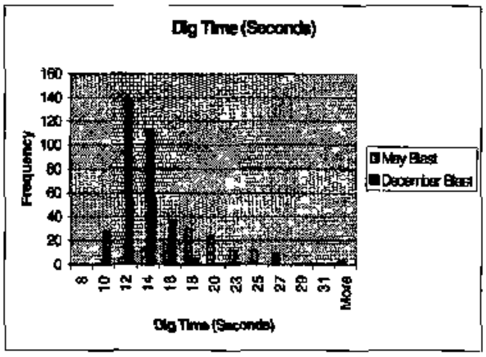

Figure 2. Dig time distribution

Video count of the loading operation in the December trial shows that 40 % of the total passes were 5 pass, the rest being 6 pass loading (total of 61 passes recorded). However, in the May trial some 77 % of loading passes were 5 pass (total of 75 passes).

Average individual truck loading time in December trials was 2:39 minutes with a standard deviation of 0:33 seconds. The May trial vlaue was 3:24 minutes with a standard deviation of 0:31 seconds. This represents 22% improvement over the May trial loading time.

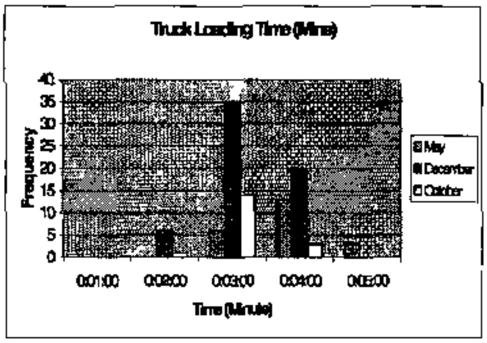

Figure 3 Loading time distribution.

The mean payload in the December trials was 192 tonne with a standard deviation of 20 tonne (Figure 4). This is only marginally greater than the May value of 186 tonne with a SD of 21 tonne. The increase in the average truck payload (approximately %3) is not statistically significant at 95 % confidence levels.

The average loading productivity (measured) is 4,213 tonne/hr with a standard deviation of 626 tonne/hr. This represents a 23 % improvement compared to the May trial result of 3,261 tonne/hr (Figure 5).

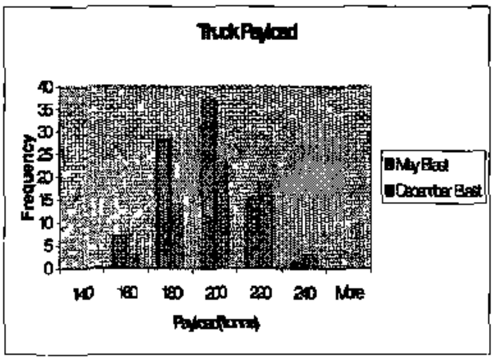

Figure 4 Payload distribution

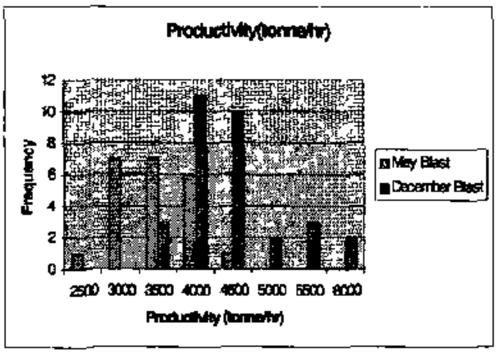

Figure 5 Loading productivity distribution.

A T-test was conducted to determine if the difference in December and May productivities is significant. The results clearly show that the difference between the May and December mean productivity is statistically significant at 95 % confidence level.

4 LOAD AND HAUL SIMULATIONS

Load and haul simulations have been performed to understand the impact of various mining parameters In the economics of the operation at the trial mine. As was the case in this study, the Dispatch was reporting abnormally high empty return times. This was discovered when the results of haulage simulations were compared with the Dispatch values.

Simulations are carried out using an in-house developed load and haul simulator. The simulator is an Excel based workbook with a small database of commonly used mining equipment. There are three major components of the simulator:

- Haulage;
- Loading;
- Costing.

Haulage is simulated using the haulroad and truck fleet characteristics. Each segment of the haulroad characterised by length, gradient, rolling resistance and speed restrictions are entered to the spreadsheet. In the loaded segments the simulator assumes that trucks are nominally loaded to their gross vehicle weights. The maximum acceleration is assumed to be 4 km/hr/s. Haulage simulations produce outputs such as speed, distance curves along the profile and times taken to complete each segment and the total haulage time. These outputs are then used in the loading spreadsheet to determine the loading productivity. User defined costs and annual operating hours are used in the cost calculations to estimate the cost of loading and hauling per tonne of material from the face to the dumping point.

The haul profile based on updated information obtained during the site visit is shown in Figure 6. The profile features multiple uphill segments designed at 10% to reach the crusher level from the face area. There is a junction on the return route where trucks *must stop.* The rolling resistances will vary from location to location in the pit. The high traffic areas such as the loading face and crusher area have been assigned higher rolling resistances. The downhill segments have a maximum speed limit of 40 km/hr.

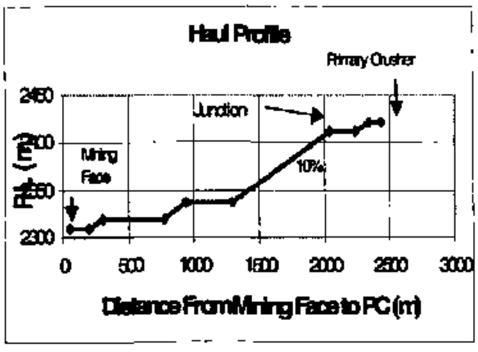

Figure 6. Haulage profile.

The average loaded haul time is estimated to be 593 seconds (from edited Dispatch records). The average empty return time is 270 seconds (from edited Dispatch data). These are in line with the measured values at the site during the experiments (Figure 7).

Assuming all other conditions are the same and no hold ups at the crusher, and with the improved fragmentation, the loading productivity increases from 3,262 tonne/hr to 4,213 tonne/hr. This gives a unit cost of $1.62 and $ 1.76 per bcm for the December and May trials respectively. This represents a saving of 9% or $0.14 per bcm. It must be pointed out that this analysis is based on the assumption that the dump time at the crusher is 30 seconds (ie no waiting time at the PC). If the waiting and dump time at the crusher is taken as 420 seconds (7 minutes) as is with the current set up, then the unit costs in May and December are $2.07per bcm and $2.21per bcm respectively. In this case only a saving of %7 ($0.14 per bcm) can be achieved with better fragmentation.

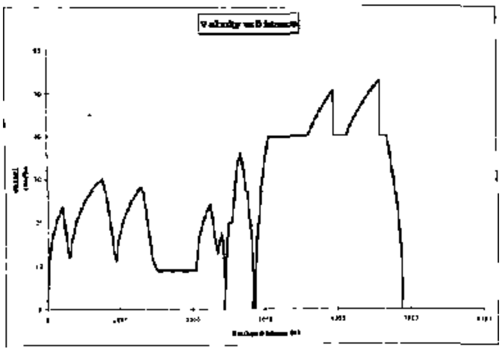

Figure 7. Speed/time graph.

The cost savings come from faster truck loading time and better fill factors only. Other cost savings such as less tear and wear of the equipment and others are not accounted for.

5 FRAGMENTATION AND FILL FACTORS

Blast fragmentation has two major impacts on loading and hauling performance of a truck shovel fleet:

- Digability (dig time)
- Bucket payload (void ratio and fill factor)

Bucket payload is a function of void ratio and fill factor. The fill factor is defined as the ratio between the nominal volumetric capacity and the volume of material in the bucket. It is predominantly an operational variable (loading strategy, operator experience and willingness to fill the bucket and the angle of repose of the material on top of bucket). Furthermore a high fill factor does not necessarily mean higher payload. If the material is not well fragmented and loosely packed inside the dipper with lots of voids between the rock fragments, the actual payload may be lower than in the case of a low fill factor but adequately fragmented and densely packed load.

The void ratio is more directly related to the fragmentation level and indicates how well the available room in the bucket is used. In other words, it is an index that indicates the effectiveness of the use of a given volume in relation to fragmentation. It is a direct indication of bulk solid density in the bucket. If the bulk density of the material inside the bucket is increased with optimised fragmentation and packing men the payload is increased. In general, as a first step to maximise the bulk density of the material in the bucket, it is advantageous to optimise the particle size distribution of the material involved.

Numerical models or physical models can be used to study the optimum size distribution for dense packing. The three dimensional particle flow code (PFC3D) package was successfully used in understanding the packing problem at the initial stages of the project. The results had been presented in die previous reports (May and October trial reports). Also a limited number of scale model experiments had been conducted to complement the PFC results (refer to the May Blast report). However the PFC models using spherical fragments may not represent the actual rocks faithfully as real materials are not perfectly spherical.

The linear-mixture packing model as developed and used in the powder technology area offers an alternative approach. The linear Mixture Packing Model as an algorithm was first proposed by Westman and Hugill (1930). Standish and Yu (1987) further enhanced die model algorithm to predict the porosity of particulate mixtures of multicomponent materials. The model is based on the analytical arguments of the packing structure of particles. Depending on the size ratio (small/large) involved, two packing mechanisms may be observed in random packing of particle mixtures:

- Filling mechanism (unmixing)
- Occupation mechanism (mixing)

Other the studies show that mere is a critical ratio of entrance, which is determined from simple geometrical considerations between the binary mixtures (Cumberland and Crawford, 1987). The above packing mechanisms have been evaluated on the basis of the following considerations. If the size ratio is smaller than the critical ratio of entrance, the packing of particles is formed by the filling mechanism. If the size ratio is larger than the critical ratio of entrance, the packing is then formed by occupation mechanism.

The payload model based on the linear mixture packing model has been developed as an VBA model. The model requires a number of input parameters including relative quantities of size fractions, effective size for each fraction and specific packing density of each fraction. The specific packing density values are especially important as it provides information on the geometrical characteristics of the bucket and material packing in the bucket. The model has been successfully used in the estimate of void's ratio of mixtures especially for small diameter particulate media. The validation of the model needs to be done for large sized mixtures with controlled experiments.

Truck by truck size distributions characterised with the X50 and n are determined using the Split image analysis software. These are used in die Payload model to estimate void ratio for each dipper load. The model estimates are based on increasing initial specific packing density from 0.4 to 0.49.

The average dipper payload is estimated by dividing the truck payload by the number of respective loading passes. Each dipper load is then derated by an historical bucket fill factor supplied by the mine site (0.84). Then the void ratio is estimated by the nominal dipper capacity and the calculated dipper load. It is assumed that the dipper is full at each loading pass.

The model estimates and the measured void ratios are shown in Figure 8. The first 30 data is related to the December trial and the last 10 points represent the data from the May trial.

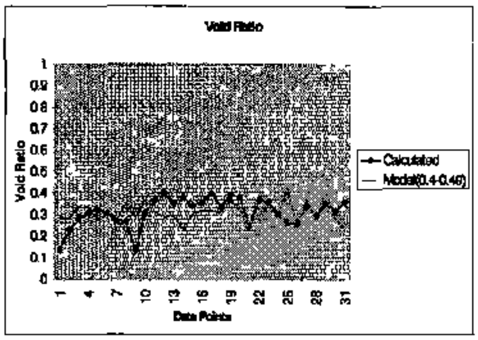

Figure 8. Void ratio and model estimates.

The variations in me measured void ratio are expected due to probable variations in the individual dipper payloads. Especially the last loading pass may not always have a full bucket load. The Payload model shows an increase in me void ratio based on the increased mean fragment size. This is in line with the previous PFC and scale model results.

The mean void ratio as estimated from the modelling studies for December trials was 0.30 with an SD of 0.035. Similarly the mean value for the May trials was 0-31 with an SD of 0.066 distribution.

Another important factor in the load haul performance in relation to fragmentation is the digability of the muckpile. The digability is simply defined here as the digging time of the loader. If the dig time is low, the muck pile is considered to have high digability, if the digging time is big then the muckpile is considered to have low digability.

The dig times as determined from the measurements done at the trial mine site have been correlated with the Rosin Rambler parameters X50 and n.

The best fit relationship (Figure 9) to the available data is:

Dig Time = a-b*X50*Un where;
a=8.9942
b=-6.8706e-2
X50 = 50 % passing size
Un= Uniformity coeffient

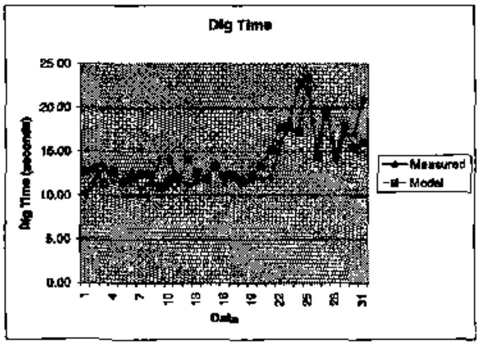

Figure 9. Dig time and fragmentation.

6 RESULTS

Due to better fragmentation, shovel dig times in the December trial were reduced by 35 % compared to the May trial from 18.8 seconds to 12.2 seconds. This is related to easy loading conditions with finer fragmentation. The number of 6 pass loading on the other hand has increased in proportion from 23 % to 60 %.

Despite the increase in the number of loading passes, the overall individual truck loading times have decreased by 22 % to 2:39 minutes in December from 3:24 minutes in May.

The loading productivity in December has increased by 22% compared to the May results from 3,261 to 4,213 tonne/br.

The increase in loading performance is a result of faster dig and swing times of the dipper and higher truck payload. This is a direct outcome of the finer fragmentation generated in the December blast.

Despite substantial improvement in' the loading performance, due to high waiting times associated with dumping at the primary crusher and time losses during haulage, this improvement may not be transferred fully into overall load and haul productivity. It is imperative that necessary upgrades of the primary crusher are made if the benefits of finer fragmentation is to be accomplished in the load and haul performance.

Cost comparison of loading and hauling has been done using the spreadsheet model on the basis of some cost assumptions. The results show that approximately a 9 % saving in loading and hauling costs {from $1.76 to $1.62 perbcm)is achievable if the haulage at the pit is optimised and also waiting time at the PC is eliminated. With the current waiting times at the crusher (420 seconds), the unit costs have decreased from $2.21 in May to $2.07 per bcm in December.

The Payload model is still under construction and validation. The model's principle is based on the Linear Mixing Model developed for fine particulate materials. However, there is a significant potential in the prediction of void ratio of mixed size rock materials.

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