Blasting Down the Cost of Taconite Pellets

by
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Abstract

Minnesota taconite producers are challenged by worldwide competition. They will need to return to the strategy that has made the Mesabi Range a leader in the industry: by applying innovative technology. Seven blast related cost reductions have the potential of saving Minnesota producers nearly $100 million per year. A powder factor increase of 50% would have overlapping benefits in: stripping, drilling, loading, hauling, crushing and grinding. Estimates are based on lab and field test results and modeling from 12 separate researchers.

Introduction

Minnesota iron ore producers have discovered that the restructuring of the 1980’s and the equipment investments of the 1990’s has not guarantee them a share of the world market. The taconite technology, developed 50 years ago in Minnesota has been replicated around the globe. High grade orebodies, favorable mining laws, lower taxes and lower wages pose substantial competitive challenges. How will Minnesota producers insure a market for their product? It will be by returning to the heritage of innovators such as John C. Greenwood and Dr. Davis. Whether it was applying large-scale excavators (fig 1), developing wash plants or magnetic separation; Minnesota stood at the forefront of open-pit creativity. By making use of Minnesota’s primary resource… not the iron … but the innovative and technological advantage. Iron is abundant. It’s the 4th most abundant element in the earth’s crust. But, the well educated and motivated workforce is unmatched in the world.

The Future

The late Julian Simon (fig 2) was fond of challenging those with a doomsday vision of the future. In 1980, Simon made a public bet with author/ecologist, Paul Erlich, that the price of certain resources would go down. Simon won. Erlich had gained notoriety in the 1970's for his books forecasting the demise of the environment and the human race. In his book, The Population Bomb, he described a future, which included commodity shortages, brown-outs, and starvation by the end of the millennium. Copper and oil were two items singled out as being critically deficient. Simon, on the other hand, reasoned that simple extrapolation of current trend lines was not a valid scientific approach. Furthermore, it was his conviction that the only commodity that we can't live without is innovation. Sensible people in a free market will find substitutions for products in short supply. Simon said that the price of oil and copper would fall, not rise, in the passing years. Today bottled water cost more than oil ($14.36/bbl) and copper ($.64/lb) is being replaced by fiber optics which is made of sand. His message and our mission is clear. We must tirelessly identify new methods and then put them to work. In short, we must be agents of change, not a victim of change. The purpose of this paper is to summarize the most promising innovations relating to the use of explosives. The cost analysis will use Total Mesabi Range volumes and estimated costs.

Blast Casting

Figure 3 Blast Casting Figure 4 Blast Casting Taconite mines experience increasing stripping ratios as pits reach for ever deeper reserves. Surface coal operators have developed methods to move up to 65% of overburden without mechanical handling (fig3,4). Increased drilling and higher powder factors are required, but overall savings can be as high as 35%. Blast casting would be well suited to expose the high grade ores of the Lower Cherty horizon of the Biwabik Iron Formation. Requirements for casting include: a flat lying ore body, a mined out floor and bench heights of 40 feet and higher. What would blast casting mean to the Minnesota iron range? Most importantly it would reduce production costs plus expand reserves. If 40 million tons of pellets are produced at a weight recovery of 28% and a stripping ratio of .5; stripping would total 70 million tons. Let's assume that only half of that stripping would be amenable to casting and that the cost reduction would only be 20%. If existing stripping costs were at $.50/LT: the annual savings would be $3.5 million per year. Even more significantly, reserves would rise. When reserves are depleted in the vicinity of the mill, large capital outlays become necessary to secure additional reserves which often add infrastructure costs as well as higher haulage costs. Those familiar with cast blasting indicate that taconite would make a good candidate for casting. The most troublesome rock types are softer formations. Airblast and ground vibration need not rise for casting since reduced burdens needed for casting have the effect of lowering peak particle velocities. Existing drilling equipment can be used, although some operators choose to drill angle holes to improve highwall stability and increase cast volumes. Current blasting agents used in taconite are the same as those used in coal casting. Initiation systems are also similar. Timing schemes for casting involve short times between adjacent holes and longer times between rows. The key is to get the front row burden moving out before the next row starts. Blasting agent consumption would rise due to higher powder factors. Assuming a current powder factor of .65 lbs/LT for waste rock and an increase to 1.15 lbs/LT; the net rise for 70 million LT of rock would be .50 lbs/LT. Required powder would rise by 35 million pounds for waste alone.

Increased productivity and Reduction of Deadloads

To quote from the ISEE Blasters' Handbook, "Large loading and crushing equipment is designed to handle a large volume of material. It is a frequent misconception that burdens and spacings can be increased because large loading equipment has been acquired'".

Trucks

Figure 5 Reduced Deadloads The metallurgy and structure of loading and haulage equipment is predicated on high impact loading (fig 5). A haul truck manufacturer has recently proposed to reduce the weight of truck boxes by 20 tons. For a 240-ton truck, that represents a significant reduction. One current strategy for lining truck boxes is to specify a design that holds up for 2-1/2 years. Trucks on a five-year lease need only one relining before the lease expires. This strategy, though good for reducing maintenance, hurts productivity. The key to reducing deadloads is to first reduce (through finer blasting) the large pieces that punch holes in the floor as they drop into the box. The oversize material in run-of-mine rock would to be at to a manageable level and the occasional large chunk would be cast aside. If impact loading is reduced, the metallurgy can be hardened to provide greater abrasion resistance. Wear patterns and life of truck boxes hauling coarse tailings, which show dramatic a difference from ore, serves as an example of what is possible. Savings in haulage would be a simple ratio 20/240 or just over 8%. Again using Mesabi Range totals and $.50/LT haulage costs; the reduction would be $8.4 million.(210 million LT times $.50/times 8%).

Shovels and loaders

Shovel and loader buckets are subject to the same economic constraints. Large pieces result in high point-loading. The productivity of loading equipment is also tied to the fragmentation. If we assume $.25/LT loading costs and the same improvement as haulage; the gross savings are $4.2 million. (210 million LT times $.25/LT times 8%)

Wall Control and Backbreak

One of the most evident and troubling characteristics of Mesabi Range blasting is overbreak or backbreak. It is defined as a zone of damaged rock lying behind the back of a blast. This rock appears to be intact and sound. However, upon closer inspection, it can be seen that gas pressure from the preceding blast has pried open the joints and cracks. The rock isn't significantly displaced and the pieces come back into approximately the same configuration. The problem is that the rock now has open gaps, separating discrete pieces. There are four major problems that result from overbreak: · unstable walls · lost reserves · broken ground · subsequent oversize fragments.

Unstable Walls/Lost Reserves

Figure 6 Designed Slope Three problems result from unstable walls. They create rockfall hazards, they invite over-digging by excavators and they result in lost reserves. The safety aspect is self explanatory and requires vigilance especially following rainstorms and during freeze-thaw periods such as in late winter. To avoid creating rockfall hazards, operators are forced to leave additional catch benches for falling material. This leads to the problem of lost reserves. Final highwalls (fig 6) are designed at steep angles to maximize ore recovery while minimizing stripping. There are examples where reserves were based on designed four to one slopes (a 20-foot catch bench below an 80-foot wall), but due to poor wall control, the actual slope was one to one (fig 7). In terms of reserves, this has a significant impact. Assume that the final wall was 300 feet high. The lost material due to the change in slope totals about 8 million long tons for each forty acre parcel (each ¼ mile of bench length)

Broken Ground

Figure 7 Actual Slope Final walls are a problem. But what if mining is continuing on the bench? Does that mean there is no problem? Unfortunately not. Drilling, on the new crest row is hampered. Note that 20% of the holes are crest holes on a 5-row pattern. Air pressure can be lost into the open cracks leading to loss of circulation. Overbreak also encourages over-digging by the excavator which means the driller must place crest row holes back from the desired location; causing crowding with the second row. Hole misplacement is serious. For example, assume a designed burden of 15 feet is increased to 20 feet. If blast energy drops off at a rate of the inverse of the distance squared; blast energy falls by nearly half Drilling rates suffer, drill maintenance suffers, re-drills are necessary and lost bits due to broken steel may result. Re-drilling holes alone, can add 5% to drilling costs. Assuming drill costs of $.10/Lt and a 10% loss in drill efficiency; Mesabi range losses total $2.1 million. (210 million LT times $.01/LT)

Oversize

The bulk of oversize fragments originate on the crest of the blast. Just as it difficult to ring a cracked bell; it is nearly impossible to get shock energy or gas pressure to enter the discrete blocks that lie in front of the crest row of holes. Large blocks may account for only 1% to 2% of the muckpile, but loading, hauling and crushing equipment must be designed to handle the abuse of oversize. The broken crest is also responsible for airblast and flyrock. Ground vibration problems are often a result of the misplaced holes, resulting in excessive burdens along the crest. The key to solving backbreak problems lies in the disposition of material which lies behind the back row of holes. All Mesabi mines count on loosening a volume of rock from behind the last row. Often called 'free digging' when more digging is found than originally anticipated; this rock is the most expensive in the blast. Pre-splitting may be needed to reduce backwall damage. An additional 20% drill and blast cost included in this model accounts for pre-splitting.

Direct Conveying

Conveying from the pit has been studied by Mesabi producers for decades. Large-scale conveyors have moved material for as low as $.05/LT. Run of mine rock has generally been thought to need crushing in past models. A 60-inch crusher may only cost around $5 million, but when associated pan feeders and auxiliary equipment are included; that cost can more than double. The key to conveying ore from the pit is to blast to a finer size. A rule of thumb for belt width is three times the width of the largest fragments. So a 72-inch and a 96-inch belt could handle 24-inch and 32-inch top sizes respectively. The savings in haulage, assuming conveying costs are $.10/LT versus $.50/LT for trucks, would be $56 million per year (140million LT times $.40/LT) for the Mesabi range.

Crushing, Grinding and Eliminating Rod Mills

Incremental cost reductions are possible when size reduction is moved from grinding circuits to crushing circuits. The reason for this is the inherent efficiency of crushing vis-à-vis grinding. Grinding is estimated to be about 1% efficient compared to 50% efficiency for crushing. A quantum reduction in cost is possible with the elimination of the least efficient of the grinding mills: the rod mill. Rod mills must be stopped to be recharged and feeding rod mills is problematic. Here, the key is to crush the ore to minus ½-inch and then go directly to the more efficient ball mills. Blasting plays a leading roll in preconditioning ore as small flaws and cracks are initiated that can later be exploited in the milling process. There is now a wealth of evidence pointing toward the weakening of rock that is exposed to the shock of blasting. Downstream savings in crushing and grinding have been estimated by Furstenau, Mertz, Nielsen, McCarter, Revinitsev, Kanchibotla, and others. Using Furstenau's estimates, overall costs may go down 10% with an increase of 25% in drilling and blasting. Nielsen estimates hard rock crushing and grinding costs at $1.60/LT and $3.50/LT respectively. Applying a 10% reduction to the total crushing and grinding cost, the net savings could be $.51/LT, not including elimination of rod mills. The Mesabi range total savings would be $70 million for a 25 % increase in powder factor.

Summary

Table 1 is an accumulation of all of the cost areas. Projections are based on increasing powder factor by 50%. Projected powder factor for waste rock and crude ore becomes 1.2 lbs/LT. Drill and Blast cost are assumed to currently be at $.25/LT. Savings for crushing and grinding are based on only a 25% increase in powder factor. This is done because of the possible flattening of the cost curves beyond actual reported field results. The number is conservative since Furstenau's estimates represents a net savings after drill & blast cost are included. Furthermore, work by Mertz, Revnivtsev(1988) and Nielsen(1995) indicates continued softening of the rock at much higher powder factors (fig 8). Elimination of rod mills would create additional savings which are not estimated in this study.

Conclusions

Operating savings are about equally split between mining and milling. Drill and blast cost is relatively easy to model as changes would made by adjusting the yield from individual holes. Drill and blast cost would rise by $37 million. Net savings are then $98.8 million. Feasibility tests can be done without significant capital expenditures. Casting, deadload reduction, and wall control testing require additional drilling and explosives. Conveying, crushing plant modifications and milling modifications will require capital, however, feasibility testing can be done with existing equipment. Note that deadload reduction is an additional $8.4 million per year for trucks if conveying is not used.

Table 1

Blast Casting $3.5

Deadload Reduction $ 4.2

Wall Control/Backbreak $2.1

Direct Conveying $56.0

Crushing & Grinding $70.0

Total mine $65.8 Total reduction $135.8

Additional D&B (+50%) $26.3

D&B pre-split (+20%) $ 10.7

Net annual savings $ 98.8

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