SIMULATION FOR EQUIPMENT SIZING
LONGWALL TO STOCKPILE

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Abstract

When longwall equipment is being specified, a nominal capacity is generally given on which to base the design of the various face and out-bye systems and components. This capacity generally comes from a nominal annual capacity requirement based on realistic utilization rates. From illustrative examples of simple system simulation, this paper sets out to show that a single nominal capacity is not sufficient to size the different systems. The manner in which the Longwall is operated and the overall system configuration and availalility can have a significant impact on overall productivity.

Introduction

When a longwall is purchased, it will have a nominal capacity expressed in tonnes per hour. This is usually the cutting capacity of the shearer and is certainly the maximum average capacity that can be achieved from the system. However, sizing the coal clearance system based on this nominal capacity will always result in problems and expecting that the long term average production is closely related to this nominal capacity is also quite unrealistic. In this paper the effect of the cutting cycle on both the peak and average production rates will be examined.

The coal clearance system in a longwall operation is usually defined as starting at the Stage Loader since this is a convenient place to separate the responsibilities of the face equipment and conveyor system. While this separation is helpful for engineering and maintenance purposes, it provides a psychological barrier between two classes of equipment that in fact are complementary in the process of removing coal from the mine.

There are currently longwalls around the world with capacities of more than 5000tph. Exactly what is meant by this is not altogether clear, but no-one expects a 5000tph longwall to be able to produce 100,000 tonnes in a day. The difference between rated capacity and mean production is usually explained away in terms of availability, reliability, utilisation and other somewhat rubbery concepts. What is rarely appreciated is that the manner in which the longwall is operated has a major influence on the productivity of the face. Most importantly for the coal clearance system, matching the operation of the face equipment with the conveyor system can increase the mean production of the mine for little or no capital cost.

Production Rates

For ease of understanding, it will be helpful to define what is meant by different sorts of production rates.

Shearer Cutting Rate	=	The Rate at which the shearer cuts
AFC Clearance Rate	=	The Rate at which coal feeds off the AFC and onto the out-bye conveyor system
Mean Production Rate	=	Total tonnes cut in a single shear divided by the time taken to complete a shear.

To illustrate this point, a number of examples are shown.

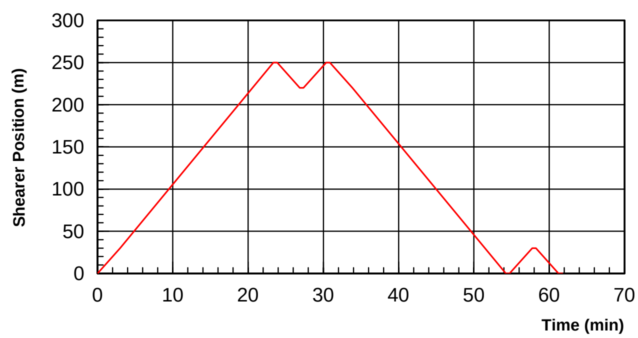

Figure 1. Shearer Position for Full Web Bi-Di Cutting.

Figure 1 shows the shearer position relative to the face of a commonly used cutting cycle. It is Full Web, Bi-Directional. This means the shearer takes the full seam height, for the full drum width as it travels along the face in both directions. The approach shown in Figure 1 has the shearer operating at the same speed in both directions for the main part of the cutting cycle, with lower speed for the stages when the shearer is cutting into the snake at either end. Figures 2 and 3 show the Shearer Cutting Rate and the AFC Clearance Rate for the above cutting cycle.

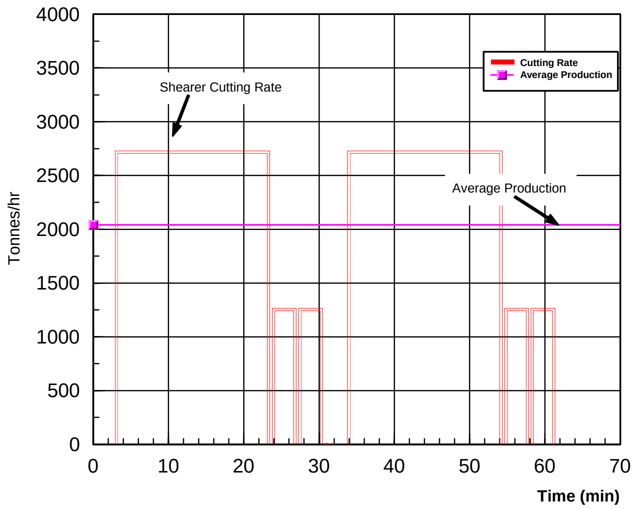

Figure 2. Shearer Cutting Rate.

As Figure 2 shows, during the cutting cycle from both Maingate to Tailgate (M-T) and Tailgate to Maingate (T-M), the shearer cutting rate is the same. However, as Figure 3 shows, due to the speed of the AFC, the clearance rate from the AFC is significantly different when the shearer moves in different directions. The cutting rate is always 2750tph, but the clearance rate on the M-T run is only 2500tph, while on the T-M run is 3000tph. While the shearer is only sized for 2750tph, the AFC and conveyors must be sized for 3000tph. It is important to notice that while the peak clearance rate is 3000tph, the average production rate for the cycle is only 2000tph. This means that even if everything is perfect, the conveyor system must be sized for 3000tph and can never produce more than 2000tph, even if there is 100% utilization and 100% availability.

If Clearance Efficiency is defined as

Clearance Efficiency = Peak Clearance / Mean Prod

Then this cutting cycle has a Clearance Efficiency of 66%. In practical terms this means that the mine must capitalise for a 3000tph coal clearance system, but even if that works perfectly with 100% availability, they will only ever get 2000tph average production. Similarly, the Cutting Efficiency is only 73%.

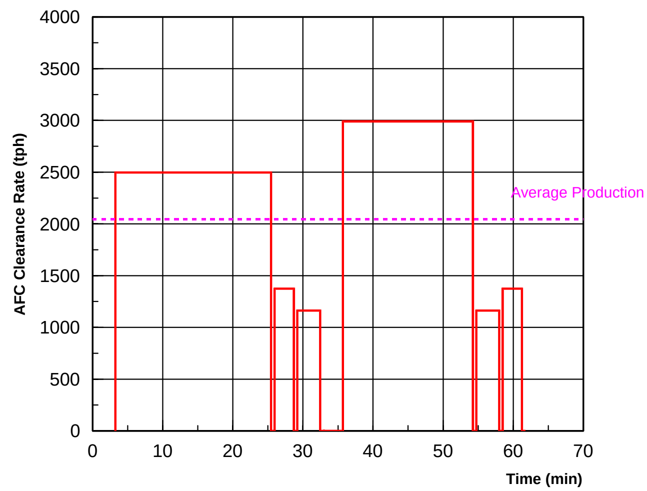

Figure 3. AFC Clearance Rate.

Of course there are ways to improve the Clearance Efficiency and most operations make some effort in this area. The most common option to get better overall performance is to operate the shearer at different speeds on the M-T and T-M Cuts. For the system to efficiently use a 3000tph conveyor system on both the M-T and T-M runs, then the shearer must operate significantly faster on the M-T run.

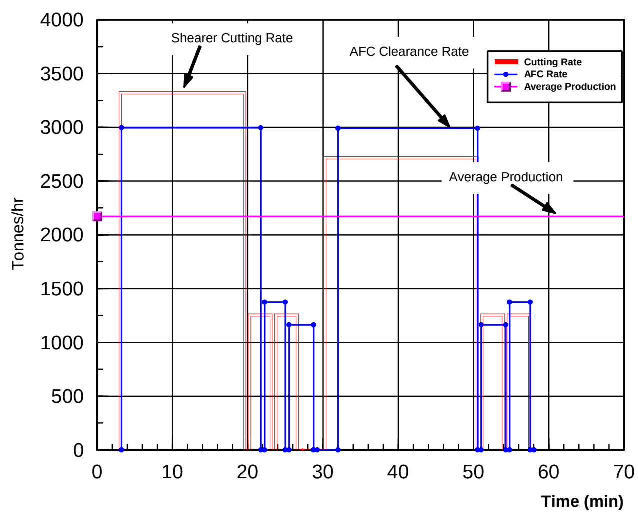

Figure 4. Shearer Speed Adjusted to Give Uniform AFC Loading.

Figure 4 is a combined graph of Shearer Cutting Rate and AFC Clearance rate with the speeds adjusted to give uniform loading on the AFC in both directions.

The new arrangement gives an AFC Loading Rate of 3000tph in both directions and an Average Production Rate of 2200tph. This means the Clearance Efficiency is now 73%. This is a significant improvement. It does however require a shearer that can cut at a rate of 3300tph whereas the constant speed option had a peak cutting rate of only 2750tph. So while the Mean Production Rate has increased by 10%, the Cutting Efficiency has fallen to 67%.

While it is clear that improved Clearance Efficiency comes at the price of decreased Cutting Efficiency, it should be remembered that as a mine progresses through its life, upgrading the shearer is relatively easy, whereas upgrading the AFC and particularly the conveyor system, is usually a much bigger task.

It is interesting to note that a significant reason for the overall inefficiency of the Full Web Bi-Di Cutting Cycle, is that the shearer spends a significant portion of its time in unproductive maneuvers at the ends of the runs. These have a greater effect on narrower faces, but are still important on even very wide faces.

There are alternate cutting cycles that reduce the amount of time spent shuffling at the ends of the block and hence increase the overall efficiency of the operation. One cycle offers significant benefits is referred to as Half Web, Bi-Directional. With this cutting approach, the shearer only takes a part of the Web in each direction so in one trip up and back it only takes one Web thickness. In this type of operation, the shearer will usually operate at the same speed in both directions, but regulate the load on the AFC by taking a different portion of the Web on the two different runs. The big advantage of the Half Web approach is that it requires less shuffling at the ends.

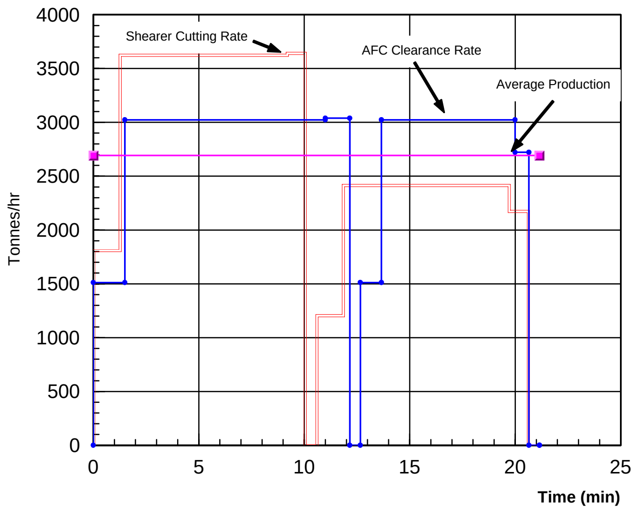

Figure 5. Half Web Bi-Directional Cutting.

Figure 5 shows the Cutting and Clearing rates for a Half Web Bi-Di cutting cycle with the same general parameters as the Full Web examples.

For the same overall production rate, a Half Web approach requires much higher shearer speeds than a Full Web cycle. This is because in a single up and back pass, the shearer will only cut one drum width, while with the Full Web cycle, two drum widths are cut. However the Half Web option does have some significant benefits.

As can be seen if Figure 5, the performance improvement is dramatic. For the same peak clearance rate of 3000tph, the average production is now 2700tph while the peak cutting rate has risen to 3600tph. These numbers give a Clearance Efficiency of 90% and a cutting efficiency of 75%, a substantial improvement in both.

The Clearance Efficiency of 90% is particularly impressive. It means that the theoretical limit on production is now 90% of the coal clearance capacity, rather than 73% for the optimized Full Web cycle, and 66% for the uniform cutting rate Full Web cycle.

These calculations show the importance of understanding the cutting approach when selecting equipment for the longwall. It is particularly important if a mine is looking for a capacity increase. The option of bigger equipment generally is always attractive and but it can be expensive and difficult to implement in an existing mine. This is particularly the case if the conveyor system needs significant upgrading. The option of a faster, higher powered shearer and a change in the cutting cycle can result in significant production increase with a relatively small capital injection.

While changes to the cutting cycle are not always simple, due to mining conditions, dust issues and all manner of other problems that beset every longwall operation, it is an option that should examined whenever a mine is limited by its coal clearance system.

Effect of a Surge Bin

Apart from modifications to the LW Cutting Cycle, the use of a surge bin close to the LW is another way of getting more coal out of the mine without a major upgrade to the entire coal clearance system. As mentioned before, upgrades to the longwall and panel conveyors are relatively easy as they can be done without disruption to the rest of the mining operation. It is the upgrading of the out-bye conveyors that are difficult as they continuously needed for both development and production. What a surge bin does is reduce the capacity requirement of the conveyors out-bye of it from the Peak Clearance rate to the Mean Clearance rate. For the Full Web Bi-Di example, an adequately sized bin would reduce the demand on the out-bye conveyors from the peak clearance rate of 3000tph to the mean clearance 2200tph. Another way to look the issue is to say that the installation of a surge bin will enable a 2750tph shearer to be used sensibly with a 2200tph conveyor system.

Proper sizing of the bin is important. Whenever bins are discussed, there is always a desire to be able to hold an "entire shear". Often this extend to holding an entire shift's production. A very large bin is needed for these conditions and is almost always uneconomical. However, it is surprising how small a bin is needed to reduce the peak clearance rate to the mean clearance rate. Figure 6 is the same as Figure 4 except that it also includes a line showing the accumulation of material in a bin, if material is removed from the bin at the mean clearance rate. ie How much material will accumulate in the bin if it is feeding out of the bin at a rate of 2200tph.

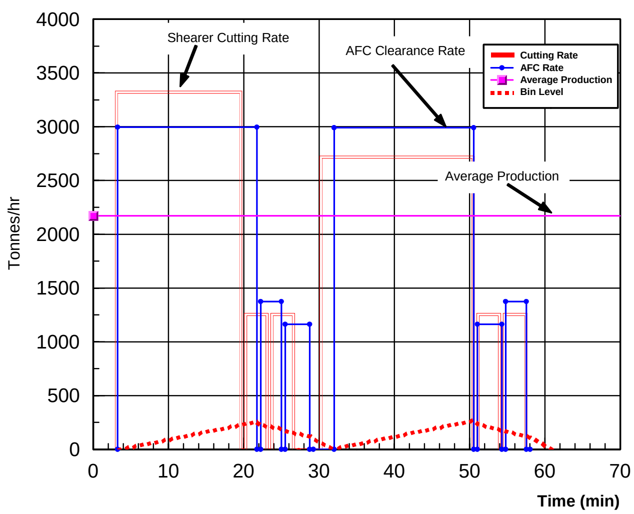

Figure 6. Bin Level
Discharge at Mean Production Rate.

As can be seen in Figure 6, the peak accumulation in the bin is 265 tonnes. This means that a 300t surge bin would be sufficient to enable the 2200tph out-bye conveyor system to operate with the longwall, despite there being peak clearance rates of 3000tph.

Availability and Re-starting

Another area in which the coal clearance system can have a profound influence on the productivity of a longwall operation is availability. This is particularly the case as the number of conveyor flights from the face to the stockpile increases.

While it is universally known that availability is vital, what is not appreciated so well is that all availabilities are not equal! In a multi flight system, the most out-bye conveyor has a disproportionate effect on the availability of the overall system. This is due the time required to restart the system in the event of a conveyor trip. If a single flight takes one minute to start, then if the maingate conveyor trips, the overall system will only incur a delay of one minute. If the most out-bye conveyor in a seven flight system trips, the overall system will incur a delay of at least seven minutes while all the conveyors restart.

Often the most out-bye conveyor in a longwall operation is a small and relatively insignificant conveyor. Frequently it is a short stacking belt or similar. This makes it far less glamorous than say a multi-tripper maingate system with torque controllable drives and sophisticated controls, or a high powered, high lift drift belt. It is, nevertheless, important to be aware that these out-bye conveyors have a greater influence on overall availability than in-bye conveyors.

Figure 7 shows the overall availability of a seven flight conveyor system with varying availablities of the individual flights and various restart times per conveyor. The modeling has assumed that there is one restart for each one percent of down time per flight. ie In a single shift, a conveyor with 99% availability will have one stop, whereas a conveyor with 97% availability will have three stops.

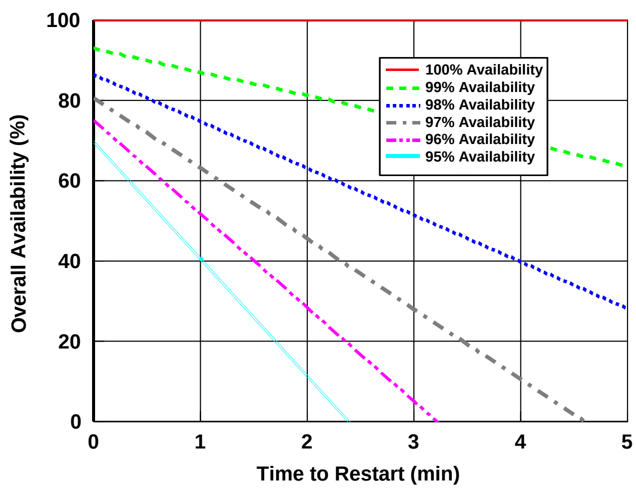

Figure 7. Overall System Availability.
Individual Availability 95%-100%

This figure shows a dramatic fall in availability as the number of restarts rises and is particularly worrying if the availability of individual flights falls below 99% or the restart time is more than a about one minute per flight.

Figure 8 shows the same information except that that it is for availabilities of 99.5% to 100%. In this figure, the assumption is that there is one restart per shift for every 0.1% down time. (This is probably not realistic as high availability conveyors usually have very few stops, but it does illustrate the point.) The results here are even more startling. Even if the conveyors individually have excellent availability, frequent short stops, and long start times will severely effect overall availability in a multi flight system.

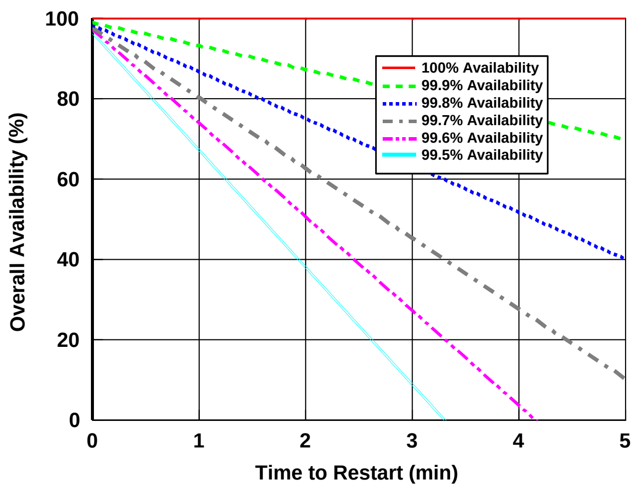

Figure 8. Overall System Availability. Individual Availability 99.5%-100%

For many modern conveyors, the starting time can be several minutes, as the start sequence includes run up and testing of various ancillary components such as pumps, fans, brakes etc. For such systems, perhaps the time has come for new ways to provide sequence for starting the conveyors.

The usual starting sequence for a series of conveyors is the most out-bye conveyor is started and once it is up to speed, a sequence command is sent to the next conveyor. It starts and when it is up to speed the sequence command is passed to the next conveyor and so on. The sequence command is often a hard wired switch, but increasingly is sent over a control network. For operations where control networks exist, there are a number of options that can significantly reduce the overall startup time. These include sending a provisional start command so that all preliminary start checks such as starting pumps and fans, pre-tensioning take-ups etc. can be achieved while other conveyors are starting. A further option that could have merit is a sequence where the conveyors start together, with the in-bye conveyors never operating faster than 80% of the next conveyor.

The networks and control systems to achieve these benefits are in place in an increasing number of mines, and there are significant benefits to be gained by implementing strategies such as these.

Conclusions

The object of the paper has been to demonstrate that nominal capacities of various items involved in Longwall production are at best only one factor in estimating the actual production rate that can be expected from a system. In particular, the manner in which the longwall is operated will have a significant impact on the sizing of the coal clearance system. In operations where this is the production limiting factor, attention to the cutting cycle may be a more effective manner of increasing overall production than upgrading the conveyor system.

The use of a surge bin to better utilize the out-bye conveyors has also been shown to be most effective.

As will all mechanical systems, availability is very important to overall production but in a multi-flight system, the effect of long re-start times is also very important. For operations that face this problem, strategies to reduce the impact of the starting delays have been suggested.