# Maximising Longwall Production by Optimising the Coal Clearance System

By: Edmond O'Donovan
Principal, E. J. O'DONOVAN & Associates
Consulting Engineers
Brisbane, Australia

Grzegorz Dewicki
Manager Advanced Technologies
Overland Conveyor Inc.
Denver, USA

*It is well understood that the coal clearance system is vital to the success of a longwall operation, since if the conveyors are not running, the shearer will be stopped. What is less understood is that matching the face operation with the coal clearance system can produce significant, overall production improvements. This paper looks at the process of matching the coal clearance system with face operation, the vital importance of high availability of the conveyors and some of the new analytical tools that are available which are integrating the analysis of the entire coal flow process from Shearer to stockpile.*

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, utisation 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 face equipment with the conveyor system can increase the mean production of the operation for little or no capital cost.

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

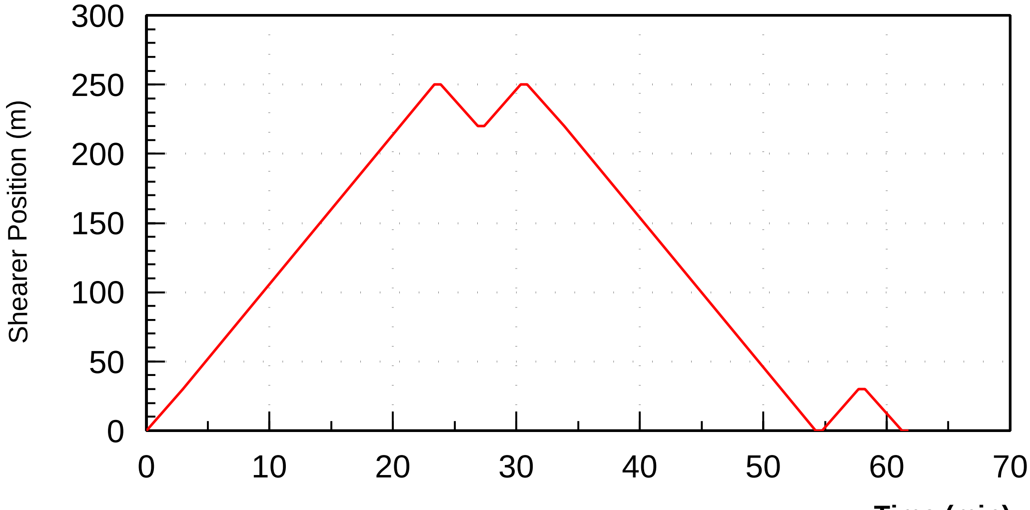


**Figure 1 - Shearer Position for Full Web Bi-Di**

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.

.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, due to the speed of the AFC, the clearance rate from the AFC is significantly different. 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. Importantly the average production rate for the cycle is only 2000tph.

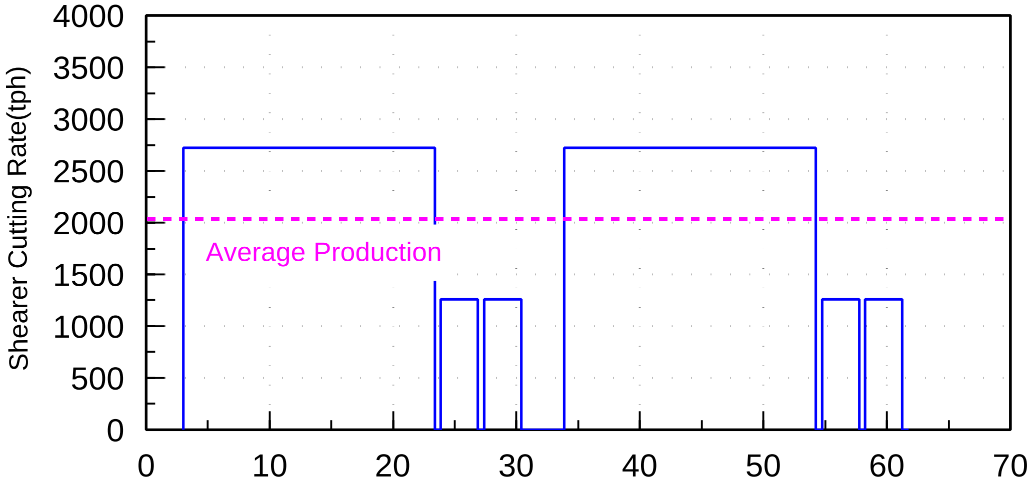


**Figure 2 - Shearer Cutting Rate**

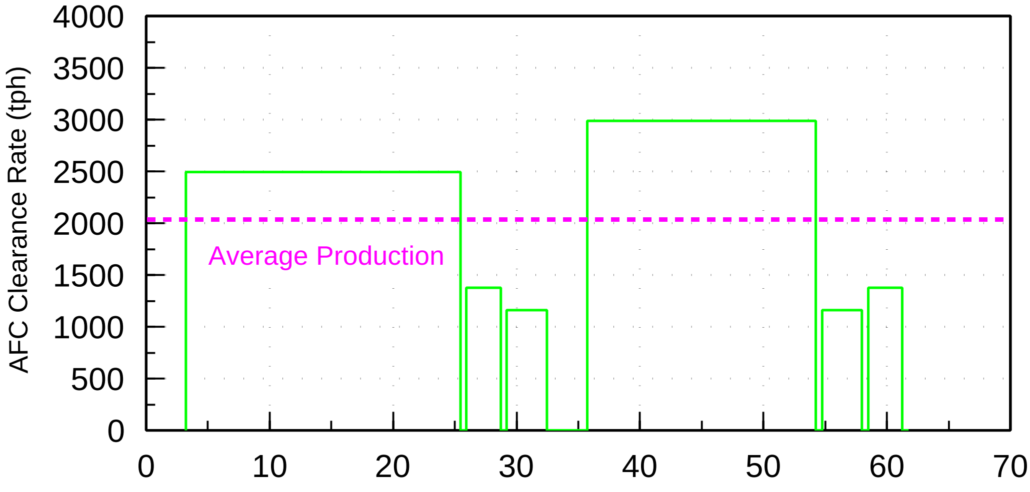


**Figure 3 - AFC Clearance Rate**

If a cutting cycle such as this is used, while the shearer needs to be sized at only 2750tph, the AFC and conveyors must be sized for 3000tph and the average production for a perfect cycle is only 2000tph.

If Clearance  Efficiency is defined as

**Clearance Eff. = Peak Clearance / Mean Prod**

then this 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%.

Of course there are ways to improve the system 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 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.  This is a Cutting Efficiency of 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.

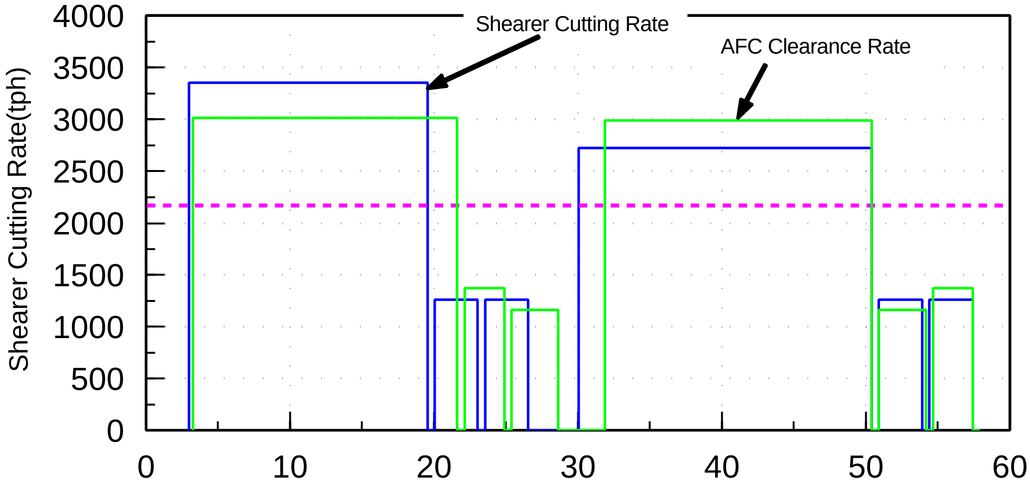


**Figure 4 - Shearer Speed Adjusted to give Uniform AFC Loading**

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 such cycle is referred to as Half Web, Bi-Directional. With this cutting approach, 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.

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.

The big advantage of the Half Web approach is that it requires less shuffling at the ends. 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.

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 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 difficult and expensive in an existing mine. 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.

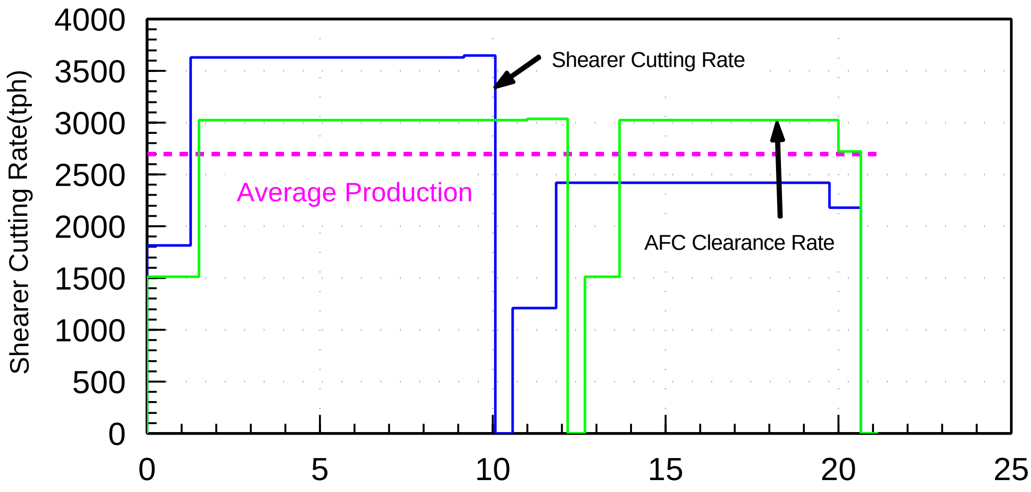


**Figure 5 - Half Web Bi-Di Cutting**

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.

A second 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.

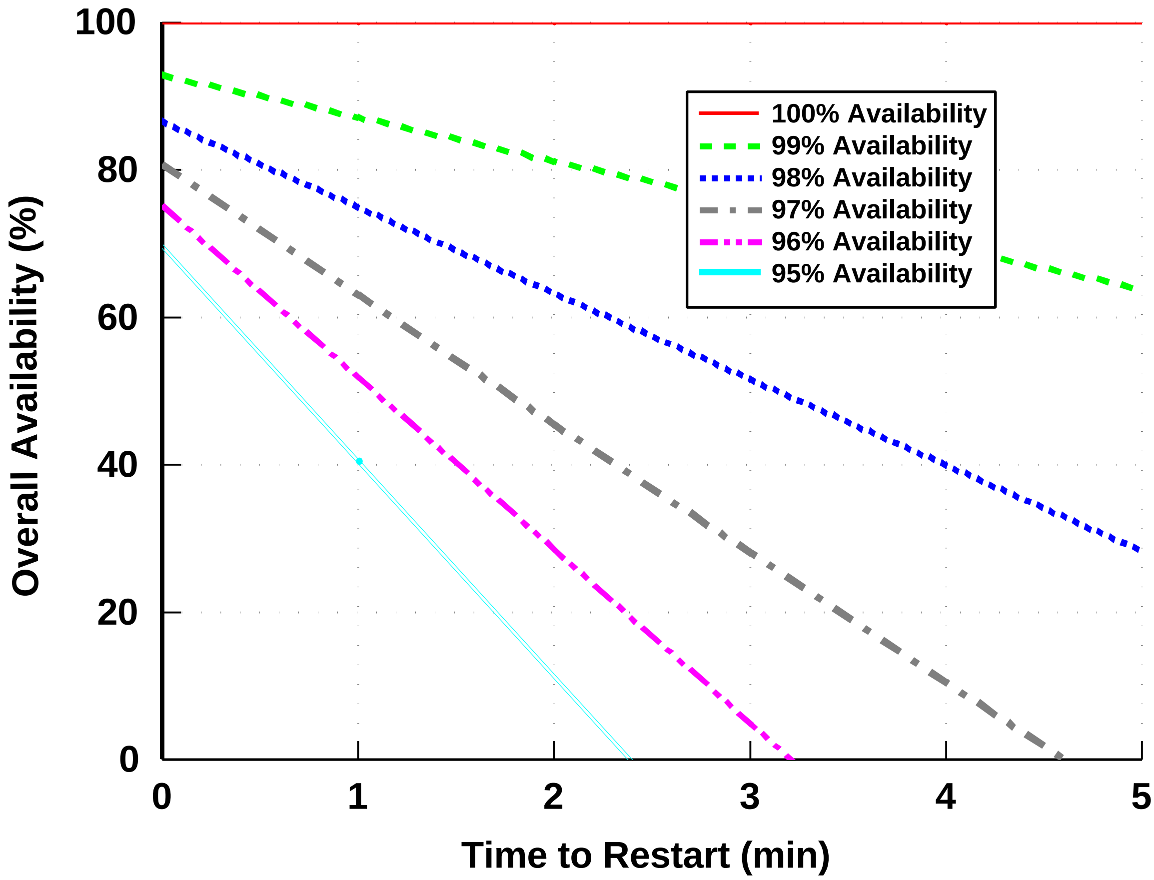


**Figure 6 - Availability for a 7 Flight System Individual Availability 95%-100%**

Figure 6 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.

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.

Figure 7 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.

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

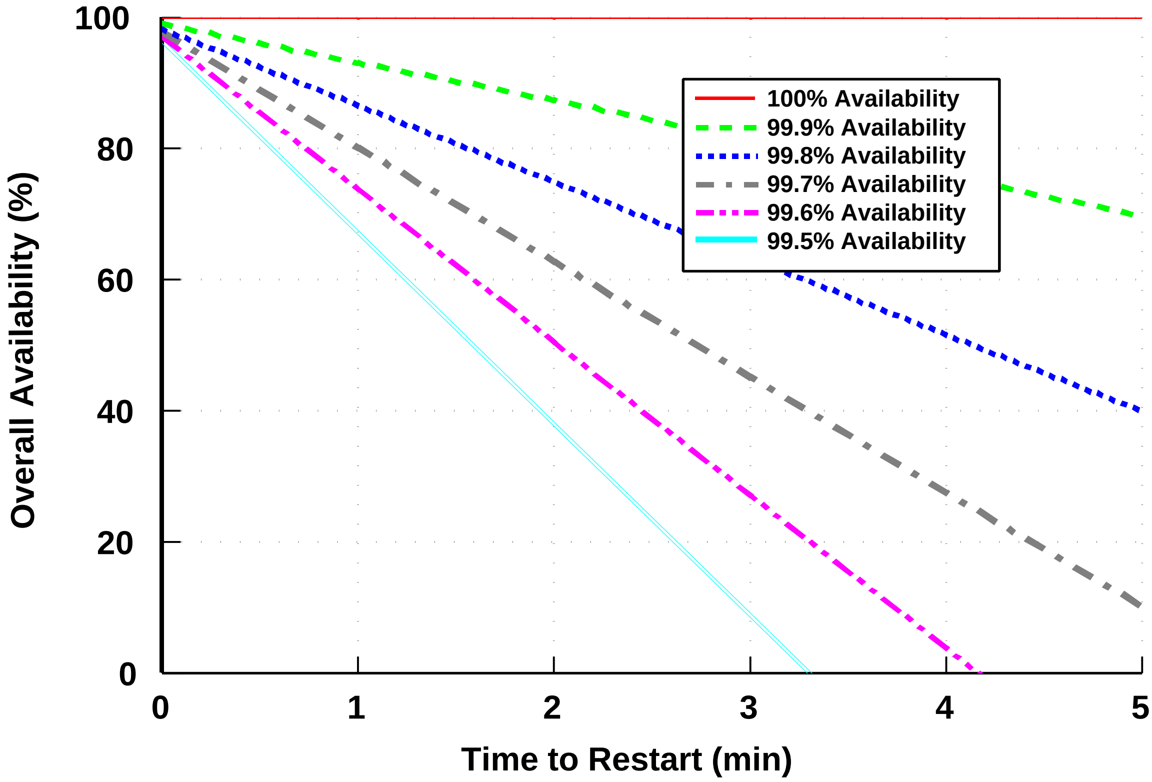


**Figure 7 - Availability for a 7 Flight System Individual Availability 99.5%-100%**

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.

As a final topic for this paper, it is important for longwall operators to appreciate the technology that is currently available for designing problems out of conveyor systems before they are installed. In recent times, the developments of modeling technology, along with the increasing power of computers, has meant that many previously intractable problems are now solvable. The two areas in which there have been the greatest advances are Dynamic System Analysis, and Discrete Element Modeling.
Dynamic System Analysis allows the designer to see all the individual components in the entire conveyor system, realistically interact on a computer rather than waiting for the system to be commissioned. The performance of different types of drives, the requirements of the control system, the speed required of take-ups etc can all be determined at the design stage. The control algorithms for trippers, the sequence and delays in starting drives, winch pre-tensioning requirements etc can all be determined analytically. As an example, Figure 8 shows a Tension vs Time Plot for the whole of a multi tripper conveyor, starting using a combination of Speed and Tension control.

This level of analysis would not have been possible even a few years ago.

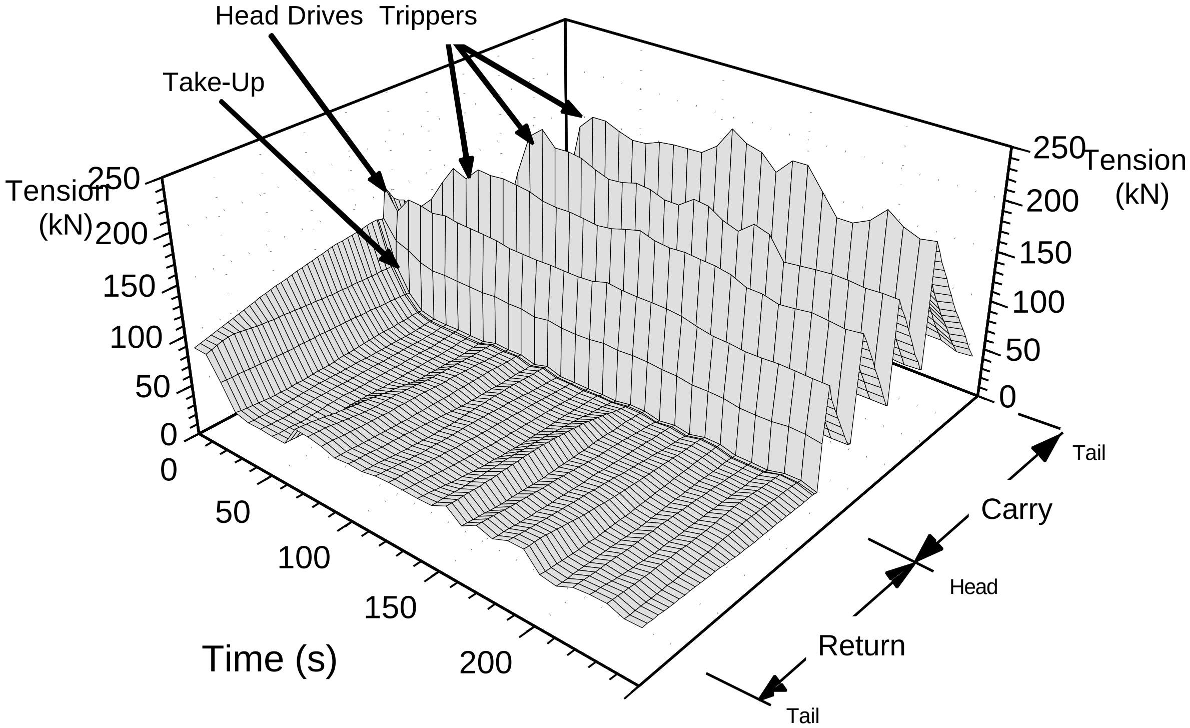


**Figure 8 Tension vs Time for a Multi Tripper Conveyor Start**

Possibly even more dramatic than the advances in dynamics are the advances that have been made in what is known as the Discrete Element Method. This technique allows the designer to examine the flow properties of a large number of individual particles. This closely represents the actual behaviour of granular material as experienced in many materials handling situations.

Figure 9 shows the originally proposed geometry, and as can be seen, the transfer has all manner of problems. Figure 10 is a modified design with relatively small changes to the geometry, and the result is almost perfect performance with the material loading centrally onto the receiving belt at belt speed.

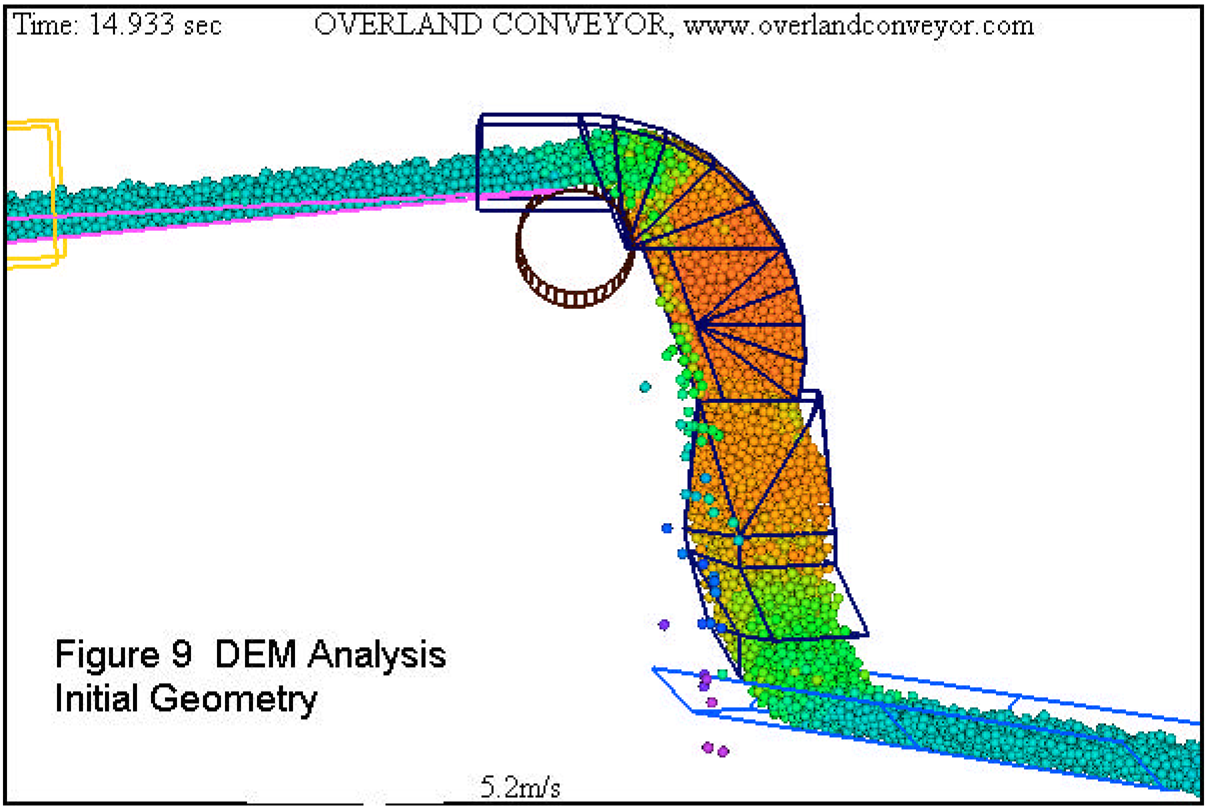


Figure 9 DEM Analysis
Initial Geometry

To date, the major area in which this method has been used in relation to conveyor systems has been in the design of transfer chutes. Traditionally, transfer chute design has been a black art, often with poor results. In fact it has remained one of the last intractable problems associated with conveyors. With the development of the Discrete Element Method, any chute geometry and a variety of material characteristics can be modeled and the resulting behaviour observed.

Figures 9 and 10 show a hood and spoon transfer analysed using DEM.

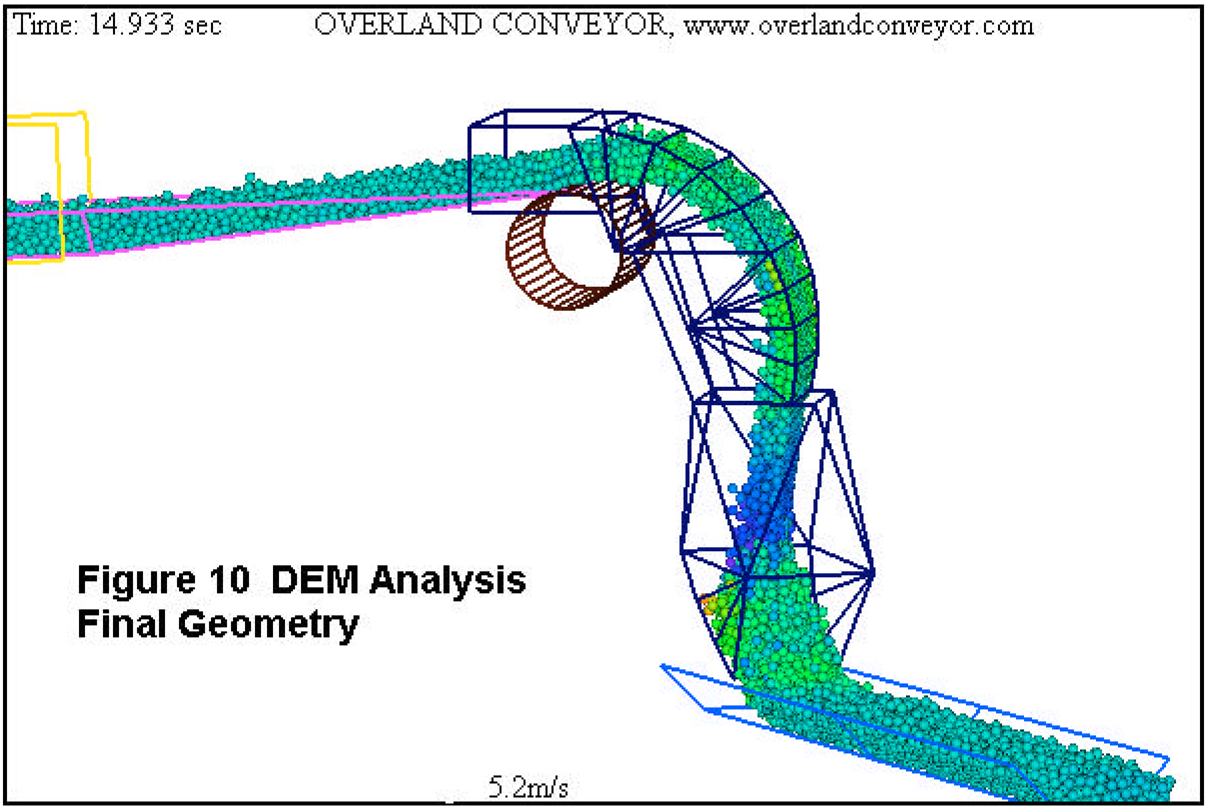


**Figure 10 DEM Analysis Final Geometry**

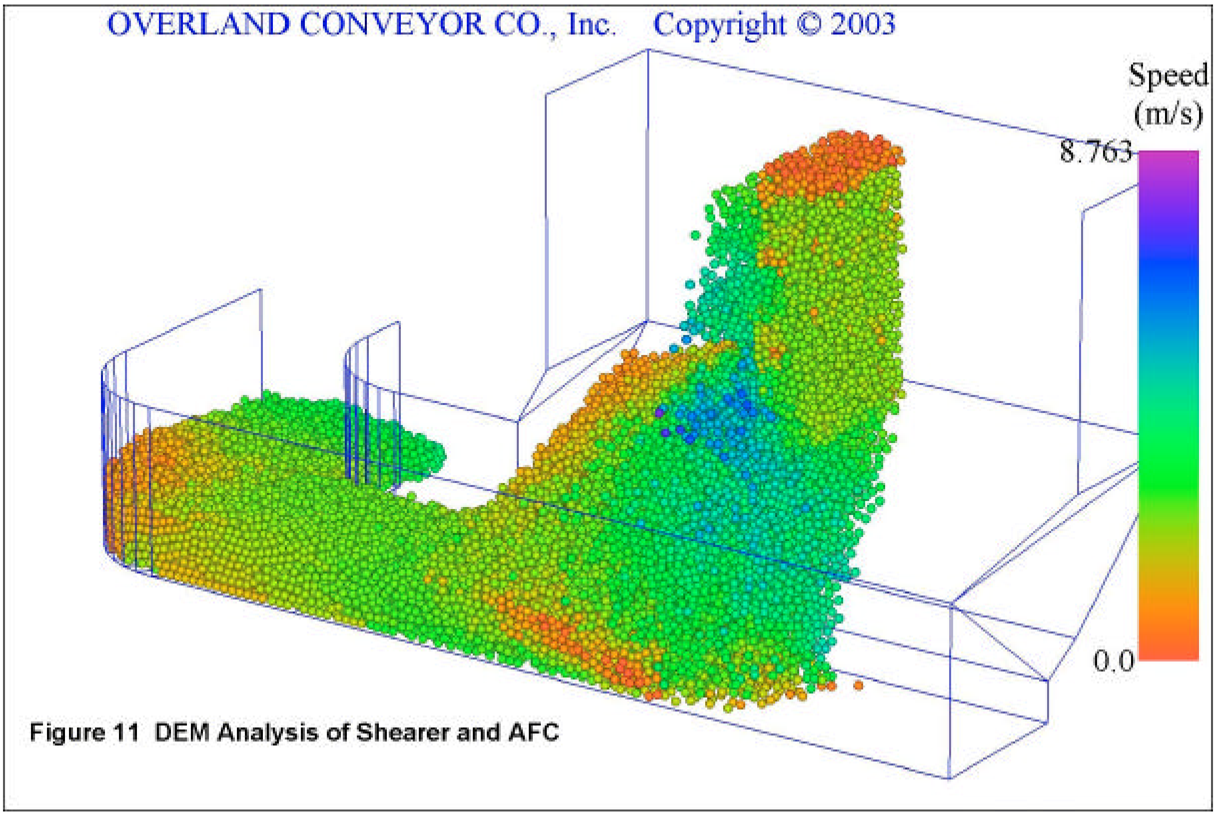


**Figure 11 DEM Analysis of Shearer and AFC**

The latest research in this field is looking at modeling the actual longwall operation, including the Shearer and AFC. Currently little or no science is used in the design and analysis of these components. With the ability to visualise the mechanics of these elements in operation, it is expected that better designs will be forthcoming. Figure 11 shows a simple model of a shearer and AFC in operation.

One of the original uses of the Discrete Element Method was in in analysing Block Caving operations. Top Coal Caving(TCC), a technique whereby additional coal from thick seems is recovered from behind the supports, is a variation on Block Caving. The use of DEM to analyse TCC and its interaction with the AFC appears to be a natural use of this developing technology.

As the coal industry advances into 21st century, it is pleasing to note that it is on the verge of having available comprehensive analytical tools that can integrate the analysis of the entire materials handing process from the face to the stockpile.