

Innovative Dragline Monitoring Systems and Technologies

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Abstract

This paper will discuss several of the systems and processes that have been developed over the past few years, and are now being utilized by major mining companies on draglines in North America, Australia and South Africa. These technologies include production monitors and reporting systems, GPS navigation systems, structural integrity monitoring systems, structural analysis studies to increase the dragline RSLs, and inspection and response strategies. The use of these technologies provides significant increases in dragline production, and reduces maintenance costs and downtime.

The question that needs to be asked is what value is there in monitoring? Increasing dragline productivity is dependent upon two items with the overall goal being to maximize the number of bank cubic meters moved and to uncover more coal: 1) maximizing payload and 2) maximizing the number of cycles. If you do not measure and try to optimize the parameters that impact payload and number of cycles, there is very little chance that you can improve overall dragline productivity. These parameters are:

Maximizing payload is dependent upon the following:

- Geology
- Blasting
- Monitor weighing accuracy
- Engage location
- Disengage Location
- Rigging
- Suspended load
- Bucket characteristics
- Operator skills
- Minimizing rehandle

Maximizing the number of cycles depends upon maximizing digging time, and minimizing cycle and delay/down times by:

- Minimizing Operational Delays
- Minimizing Mechanical Delays
- Minimizing Idle time
- Minimizing Walking time
- Minimizing Fill Time
- Minimizing Swing Angle
- Maximizing Swing & Return Rates
- Minimizing Spot Time

A third reason to monitor, conduct structural analysis studies, and have inspection strategies is to prevent catastrophic failures such as shown in the following photographs (figures 1 & 2).



Figure 1



Figure 2

Dragline production monitoring systems provide the means of measuring these parameters, and thus improving overall productivity and reducing costs. They can also help to monitor against and prevent catastrophic failures. The technology has progressed significantly since the early 1980s when the monitors consisted of swing counters and paper tape monitors logging swing counts and swing time. A number of companies have developed dragline monitors during the past 25 years. ISI or PMI Technology first introduced electronic monitors into the North America. Today Caterpillar (Aquila/DCS) and Leica Geosystems (Tritronics) dominate this market. The Pegasus system is also making in-roads in the Australian market. These systems take full advantage of modern electronics which improves their reliability, accuracy, and user interfaces. Today, the operator displays are color touch screens that provide a considerable amount of production, navigation, and maintenance information in real-time to the operators (figures 3 & 4). In addition, all of this data is transmitted via an RF link to the office server where it is converted from the raw data to summarize information for use by operations, engineering, and maintenance to evaluate the performance of operators and the draglines.

As discussed above, there are critical phases in the dragline cycle over which the operator has considerable control (fill time, swing angle, return time, spot time, etc.). Without providing real-time feedback to the operator on these items, he has no way of determining how well he is performing and thus cannot improve his overall productivity. By monitoring the data from the display, the operator can track the key operating parameters and in turn impact productivity. To provide further feedback, Tritronics (Leica) introduced real-time Key Performance Indicators (KPIs) several years ago. The system constantly checks the operator's performance against that of his peers on key phases of the cycle that impact overall production so that he knows how he rates against the other operators (figure 3).

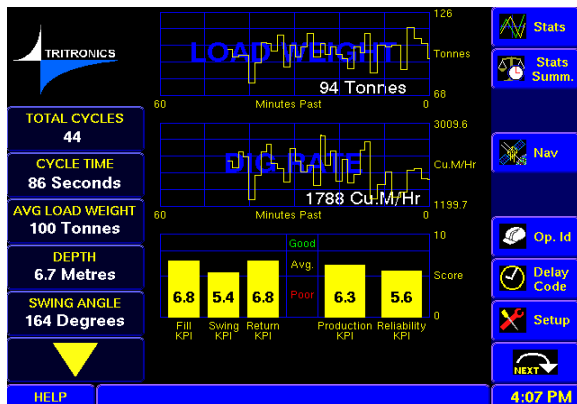


Figure 3

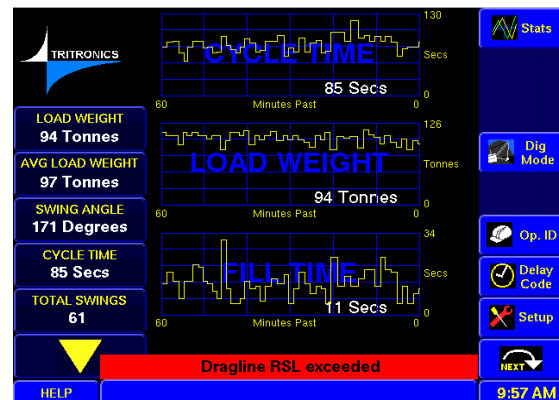


Figure 4

A dragline is a weight-limited machine, and today's monitors can accurately measure bucket weight to 5% or better. This allows the operator to view the actual material weight in the bucket, and to know whether he is under or overloading the bucket. As with the cycle information, this critical parameter impacts the overall productivity, and alerts the operator as to whether he is exceeding the target bucket weight. Constantly overloading the bucket can cause damage to the dragline structure and electrical/mechanical systems. A RSL (rated suspended load) limit can be established from the office so that if the RSL limit is exceeded during five consecutive cycles, the operator receives an alarm on his display (figure 4). The alarm information is also recorded in the office database.

The data from the on-board systems is transferred to the office via an RF link. The system manufacturers offer database software with a variety of standard reports (figures 5-7), as well as providing the ability to do custom queries, or export the data into Excel or Access (figure 8) for more detailed engineering analysis. These reports provide operations or engineering with details on the dragline or operator performance and measure the key productivity indicators discussed earlier. All time events and delays

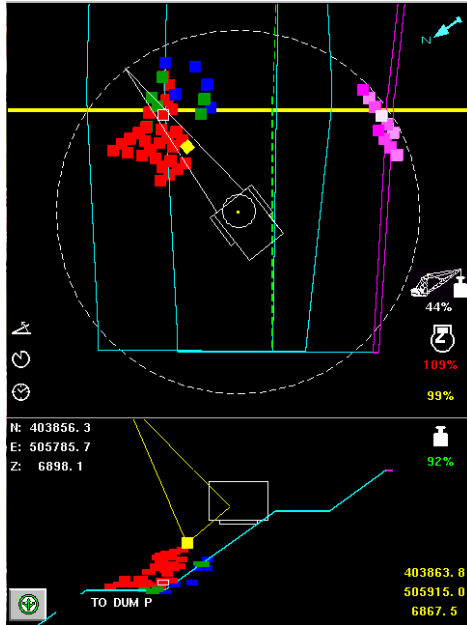


Figure 9

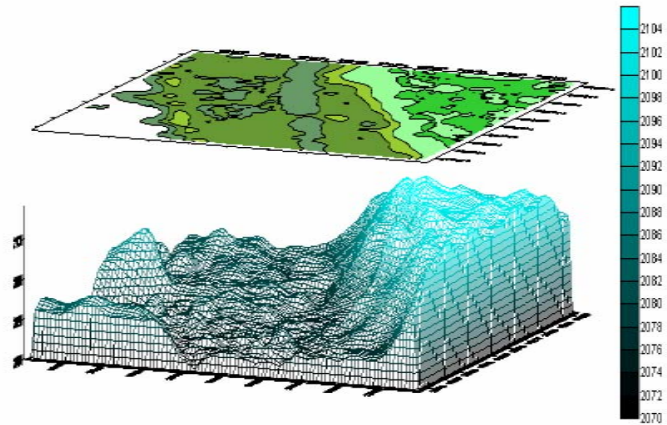


Figure 10

Several of the reported benefits of adding HPGPS to the draglines include:

- Increased tons of coal uncovered and lower coal dilution
- Minimizing rehandle
- Smoother bench floors
- Optimal spoil-side bench design and construction
- Reduced dozer pad pushing requirements
- Precise tub positioning leads to:
 - Enhanced safety around highwalls
 - Correct positioning in less time and with less wasted movement
 - Overall lower maintenance and operating costs
- Build a topography based upon the bucket dig and dump positions (figure 10)

Modern dragline systems have the capability of calculating a Diggability Index for each bucket moved based upon the energy required to fill the bucket, the fill time and drag distance. The Diggability Index is a good indicator of the effectiveness of the drilling and blasting program, and how well the overburden has been fractured. However, prior to the development of the HPGPS systems for the draglines, the Diggability Index was not too meaningful because the bucket position was not known; and therefore, the Index could not be tied to a specific location. Today, that data is available as illustrated in figure 11. The green, blue and red dots are the fill positions with the colors representing the relative Diggability Index. The yellow squares are the tub positions and purple dots are the dump positions on the spoil.

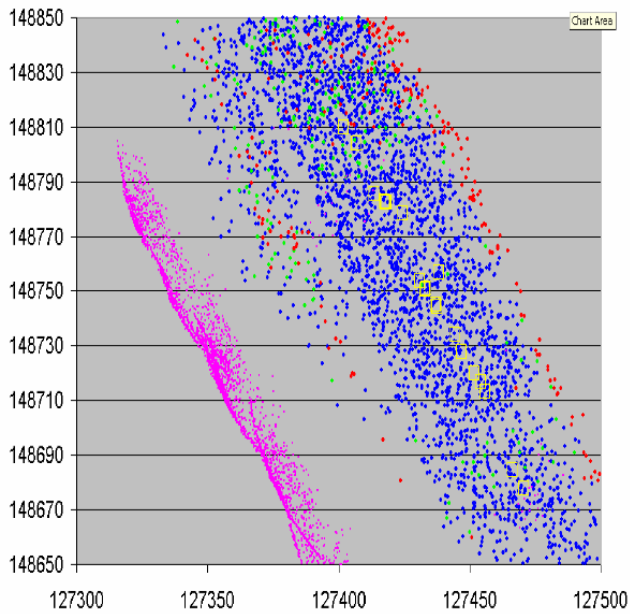


Figure 11

BHP’s Navajo mine in New Mexico has taken this a step further and has begun to directly relate drilling information to the dragline Digging Index (figure 12). The goal is to alter the hole burden and spacing and/or powder factors to optimize the fragmentation and thus the productivity of the dragline.

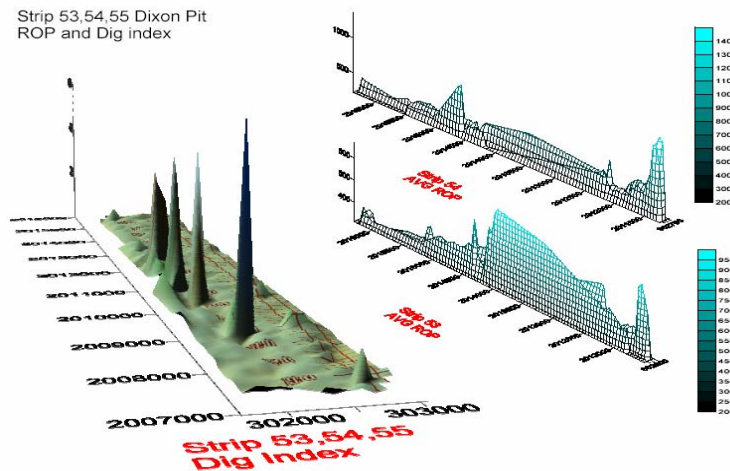


Figure 12

Dragline preventive maintenance is critical to reduce downtime and maintenance costs, and to prevent catastrophic failures. WBM and Leica (Dutymeter) offer a basic strain gauge monitoring system to look at stress in a couple of key locations on the dragline boom. Feedback is provided to the operator in the case of Leica’s Dutymeter system in the form of a Duty or Reliability KPI as shown in Figure 13. Excessive stress caused by poor operating practices can also activate an alarm which has preset alarm levels. Data from these systems is transferred to the office and a variety of reports (figures 14 & 15) can be generated. This information can be used to correct operating practices which are causing excessive boom stress. BHP Navajo have also used the information to assist with the “tuning” of the boom.

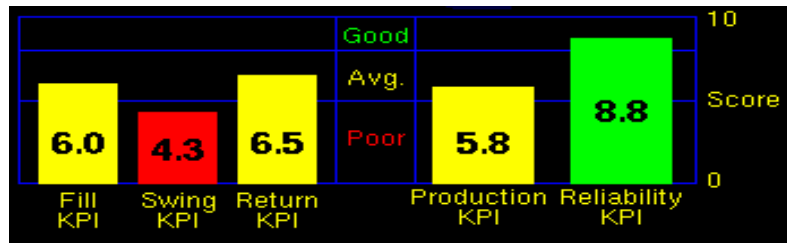


Figure 13

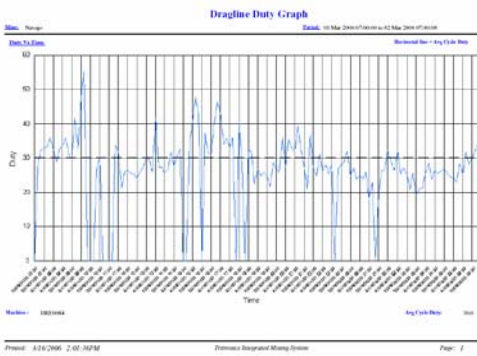


Figure 14

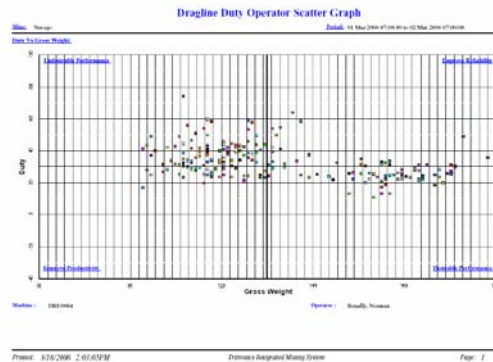


Figure 15

SIM Pty Ltd, in Melbourne, Australia and Leica have gone a step further and jointly developed a more sophisticated Structural Integrity Monitoring system (SIMS) that uses multiple strain gauges located on the boom and A frame, and can be incorporated into the suspension ropes. This system measures both stress and fatigue, and with more inputs (up to 30 strain gauges plus a boom sheave angle sensor), it can accurately measure the complete structural integrity of the dragline. The operator display (figure 16) shows the location of each strain gauge, the percentage of its preset limit, and colors are used to quickly alert the operator to out-of-limit conditions. The data is also sent to the office server where standard reports are used to analyze the data (figure 17). Some of its other features include:

- Pre-emptive warning to prevent exceeding strength criteria
- Out-of plane angle criteria set (based on analysis for specific dragline) to alarm/warn operators to prevent exceeding the strength limit by swing prior to pick up. The critical out of plane angle will vary depending on the bucket pick up position and the hoist capacity of the dragline.
- Checks for hoist stall – warns operator prior to stall if hoist angle and corresponding out of plane angle is outside pre-set threshold values
- Provides real-time feedback to operator
- Can provide signal to PLC to stop picking up bucket
- Limits hoist rope force if out of plane angle exceeds pre-set limits when pick up commences



Figure 16

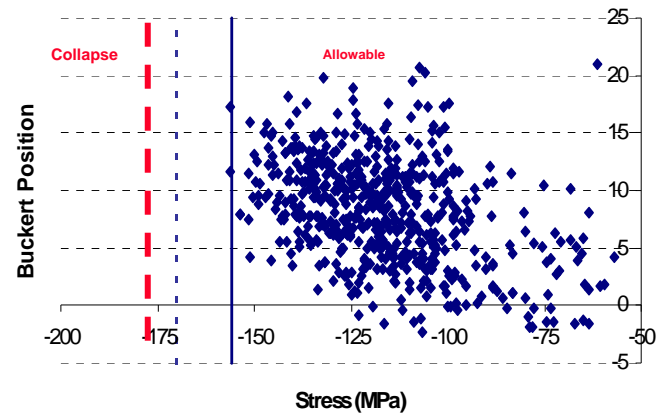


Figure 17

A complete structural analysis study of a dragline is another methodology which can be employed to safely increase the payload and to identify weak structural members in order to prevent catastrophic failures. To date, the Maintenance Technology Institute in Australia has completed such studies on over 50 machines in Australia and South Africa, as well as three BHP and Peabody draglines in the United States. The key steps in the MTI methodology are:

- Review past performance of the draglines and correlate with similar draglines the operational data and the history of failures, repairs, modifications and maintenance
- FE modeling and analysis
- Instrumentation and the gathering of actual operating data from the dragline
- Derive stress profile for the structure
- Identify critical members of the structure
- Risk assessment based on adapted methodology

The deliverables from these reports include:

- Dragline capacity – Maximum Safe Total Suspended Load (TSL)
- Compliance with design criteria and the factors of safety
- Member upgrades for operating at higher RSL levels – up to 125% RSL within a safe working envelope
- Operational parameters that influence capacity and fatigue damage
- Optimal bucket size for operating within a safe working envelope

Several examples of the results of these studies are: 1) a Marion 8750 with an original RSL of 306 tons is now safely working at 383 tons; 2) a Bucyrus 2570, which was originally designed with an RSL of 363 tons, following recommended upgrades to the boom, is now working at 400 tons; and 3) a Marion 8200 in Gillette, Wyoming was able to order and safely use a larger bucket without any structural upgrades. As a result of these dragline structural studies, there have been millions of dollars gained through increased production and reduced maintenance costs.

Another service MTI provides is to develop a risk based inspection and response strategy for the dragline structures with the goals being to:

- Reduce risk of catastrophic failure (detect cracks before critical size)
- Eliminate unscheduled stoppages (early detection and scheduled repair)
- Ensure/enable targeted inspections (know exactly when and where to inspect)
- Enable factually-based decision making (when should repairs be conducted)

The strategy identifies:

- Location and failure probability as a function of criticality
- Inspection frequency based on criticality and crack growth rates
- Detailed inspection checklists
- Standardized inspection procedures (inspection methodology)
- Criticality and repair/monitoring strategy (stop machine, repair on next PM day, fix within three months, etc.)
- Monitoring procedures – tracking status of defects

In conclusion, with the availability of dragline performance monitors, HPGPS navigation systems, structural monitoring systems, structural analysis studies, and inspection strategies; all of the tools are available to significantly and safely improve dragline productivity by increasing payload and the number of cycles. Most important, this increase in productivity can be achieved without increasing maintenance costs or causing a structural member to fail which might lead to a catastrophic failure. While these systems are not inexpensive and require management's commitment to insure the data is used to implement change, the payback or return on investment is significant.