

## RELIABILITY IMPROVEMENT THROUGH SMART LONGWALLS PROJECT

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### Introduction

Coal produced by Longwall mining is almost 30% of the total coal production in Australia, distributed between NSW and QLD and with production tonnage and face numbers as shown in Figure 1.

Traditionally, Australian longwall miners have favoured large equipment to keep the unit costs down. While this enabled longwall production to enjoy productivity figures approaching those for some open cut mines in Australia, the low availability and utilization have made it difficult to extract maximum use from installed capacity.

Typical downtime figures in Australian longwalls are around 60% of the calendar time, most of which are associated with face equipment failures. Therefore, a critically important element of the Australian drive towards catching up with world's best practice in higher utilization of the installed capacity, is improving face equipment reliability.

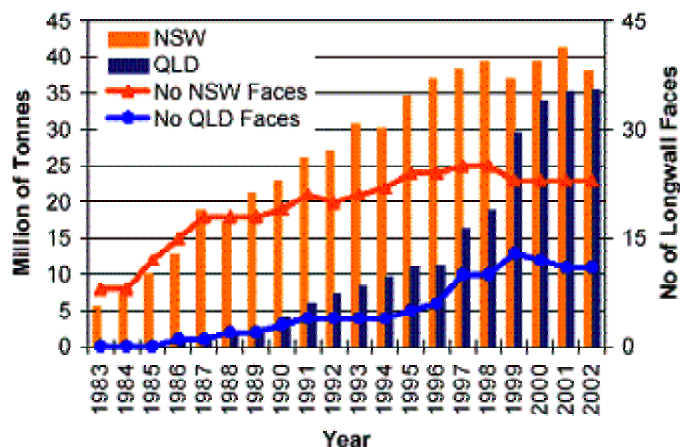


Fig.1 Longwall face number & production in NSW and QLD (Joint Coal Board)

CRC Mining Smart Longwalls Project is aiming to achieve a significant increase in longwall productivity by improving the reliability of face equipment to benefit its members. The immediate target for reliability improvement of face equipment is to quickly identify the failures and their root cause by modeling, data collection and analysis, fault detection, and condition monitoring. The long-term target is to eliminate some faults by re-design & re-engineering, fault prediction and automatic avoidance of the fault.

## Common failures in Longwall face equipment

The research priorities in Smart Longwall project have been developed by surveying equipment failures in selected sites. A Pareto-style representation of top 50 production delays in a survey site is shown in Figure 2. This figure shows that the top 10 delays account for almost 55% of total failures and the top 4 delays alone account for nearly 30% of the total failures. These points are summarised in Table 1.

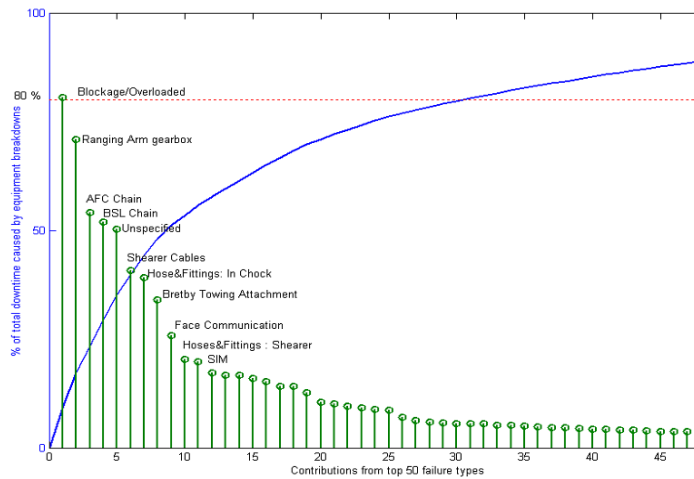


Fig. 2. Ranking of top 50 longwall face equipment delays

Table 1 Top delays in a face equipment

		Contribution to total face equipment downtime
Top 50		~90%
Top 10		~55%
Top 4	AFC Overload	~30%
	Ranging Arm Gearbox	
	AFC Chain Failures	
	BSL Chain Failures	

A better representation of the delay ranking is given by a scatter plot, which plots Mean Time To Repair (MTTR) against number of breakdowns. This is shown in Figure 3.

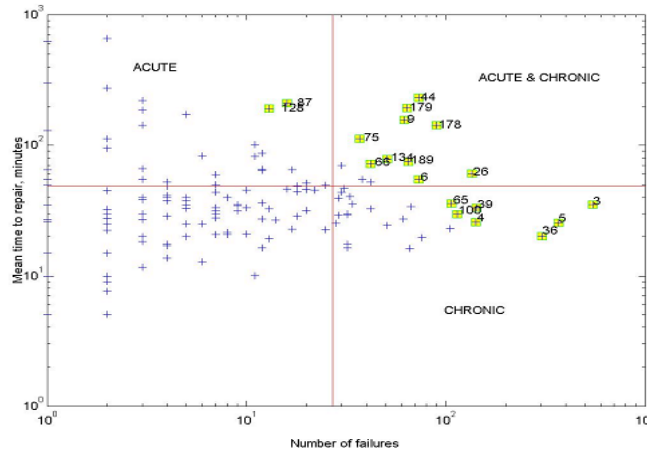


Figure 3. Scatter Plot for longwall face equipment failures

The scatter plot representation, as first suggested by Knights(2001), is a useful tool to represent the distribution of the downtime categories in a given equipment system. In the scatter plot, the graph area is separated into four quadrants. The lower left quadrant includes those failures that do not appear too often and are easily fixed. Attention should be focussed on the other three quadrants: Acute; Chronic; and Acute & Chronic. Among the top 4 delays being identified, the top 1 delay (AFC Overload as marked 3 in Fig.3) is a chronic problem and the top 2 to top 4 delays (Ranging arm gearbox, AFC and BSL chain failures as marked 44, 178 & 179 in Fig.3) are acute and chronic problems.

According to Figure 2, the single largest contributor to downtime is caused by overloading of the AFC drives due to excessive material accumulation on the chain conveyor. The second largest amount of delay time is caused by failures associated with the shearer ranging arm. AFC/BSL rank third and fourth in terms of the production delay.

### ***Smart longwall projects***

The CRCMining Smart Longwall projects are selected to deliver significant reliability improvements on the top 4 delays mentioned above. These are either Acute & Chronic problems or Chronic problems in the scatter plot terminology of Figure 3. The focus on the remaining top 50 delays is to be maintained through a continuous improvement program. The major projects in the CRCMining Smart Longwalls work area are described below.

#### *Fault Detection using Citect Data*

A Neural Networks model has been developed by Bongers(2003) to detect and identify equipment faults using large quantities of data collected on-line through the Citect software, which is a remote data acquisition system commonly used in the Australian longwall industry. The work so far has proved the feasibility of detecting progressively

developing failures, including blockage/overload stoppages, temperature trips and dupline faults.

The outputs of this project can help the industry improve face equipment reliability in the following manner:

Firstly, it improves the accuracy of data recording by automatically generating daily or weekly statistics such as:

- uptime
- downtime
- no of stoppages in each shift
- average production delay

Such statistics can be automatically compared against manually entered data for purposes of improving record keeping practices. Reliable data recording is essential in selecting and implementing projects to deliver substantial improvements in reliability and measuring their effectiveness.

Secondly, the fault detection software in its present state can detect the development of longwall equipment faults several minutes in advance of the occurrence of each failure. The following fault types have been identified with misclassification rates lower than 20%.

- Maingate Drive Assembly Cooling Fault
- Armoured Face Conveyor Blockage (maingate)
- BSL Drive Stall
- BSL Dupline Fault

Through a continuing program combined with reliable data recording, this list can be augmented to cover most if not all of the progressive faults, ie production delays that develop over time. Provided with an early warning about an impending fault, operating conditions can be manually or automatically adjusted to avert it.

#### *Shearer Modelling / Pick Force Estimation*

CRCMining Cutting Head Performance Analysis Software (CPAS) is able to check a drum design against excessive vibrations and inefficient cutting conditions by predicting the reaction forces and shaft torque acting on a drum and drawing its breakout pattern (Tiryaki, 2003). The software allows engineers to predict the vibration characteristics of the shearer drum before it is mounted on the shearer. This makes it possible to optimise the shearer drum design for a particular site, minimising the likelihood of premature shearer failures caused by excessive vibrations and force fluctuations during shearer operation.

The predictive capability of the software will be calibrated against force and vibration measurements from two Australian longwall sites, as part of an ACARP-funded project. The CPAS computer model is also used as a virtual machine in a project where CRCMining PhD student Anthony Reid is working towards a methodology for on-line estimation of individual pick forces.

#### *AFC dynamic modelling and chain tension monitoring*

The integrity of AFC chain is a critical factor in overall AFC system reliability. The AFC chain dynamics play a significant role in this context.

CRC Mining developed a dynamic model of an AFC system including the electrical drives and power transmission and implemented the model in a computer program (Wauge, 2003). This program has subsequently been applied to a number of sites to study the performance of different AFC drives under different panel geometries and loading scenarios.

To verify the model predictions, the CRCMining Smart Longwalls research team embarked on a project for in-situ determination of the AFC chain tension in an ACARP-funded project. An AFC Chain Tensionmeter was designed and built in the form of an instrumented flight bar. The aim in this project is to measure the AFC chain tension under different operating conditions including straight runs, snaking, carrying coal and/or stone, stalls and recoveries. The results of these tests in combination with the AFC model predictions will help CRCMining researchers better understand the mechanisms of AFC failures and develop operational and maintenance strategies to eliminate them.

#### *Investigation of Optimum Maintenance and Production Practices*

This is a collaborative project with an actively participating Capcoal longwall site. A simplified version of the fault detection and isolation software has been implemented at the target site. This helps the CRCMining research team automatically record the daily or weekly statistics of uptime, downtime, number of stoppages and average production delays. Improvement work can be undertaken once failure patterns are identified correctly through this work.

Detail review of the previous maintenance planing and operation procedure will also be conducted to form the optimum maintenance strategies for the longwall sites as part of this project addressing the top 50 delays identified in earlier work.

## Smart Longwalls Project Findings

This section includes the results of the reliability analysis of longwall equipment and the results of AFC simulation. The results of the fault detection are presented in a separate paper presented at the CRCMining 2004 Conference.

### *Findings of the Reliability Analysis*

The failure probability distribution functions for the top delays have been identified. The identification of the failure probability distributions has significant impact on the maintenance strategy since it will reveal the effectiveness of the maintenance activities. A failure distribution that has a constant failure rate is called an exponential probability distribution and the reliability of the equipment having such category of failure distribution cannot be improved by the preventive maintenance. A time-dependent failure distribution such as Weibull distribution can determine whether some preventive maintenance is effective or harmful since a Weibull distribution may be used to model both increasing and decreasing failure rate. If the equipment shows an increasing failure rate, the PM may be useful to improve the reliability. If the equipment shows a decreasing failure rate, the PM is harmful from the reliability improvement point of view.

All delay data sets are plotted on semi-logarithmic coordinates to test the goodness of the exponential fit and log-log coordinates to test it against a Weibull fit. The straight lines correspond to the best fitting lines in either case.

The probability plots for number one delay (AFC Blockage) data collected in 2002 in the project test site is shown in Figure 4. A Weibull distribution seems to offer a good fit.

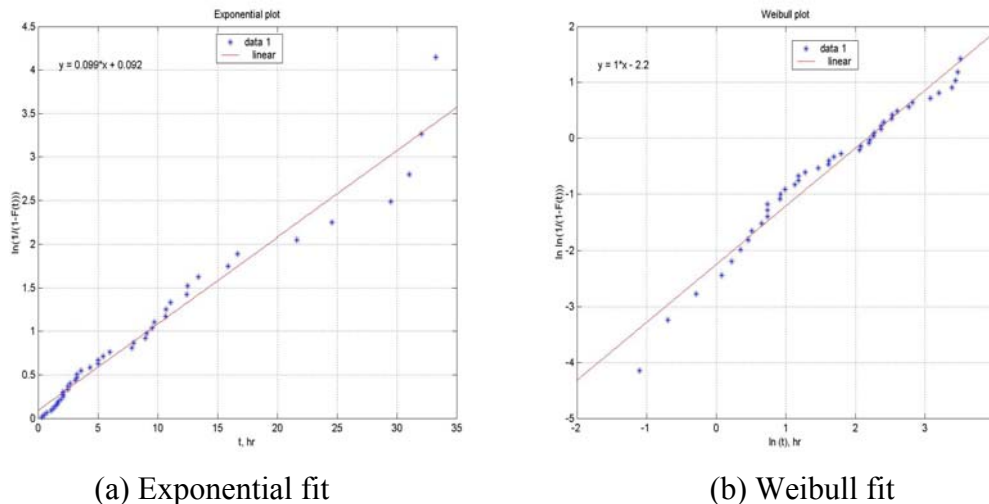


Figure 4 Probability plots for Blockage/Overload data

The two charts in Figure 5 show the probability plots for data of shearer ranging arm failures collected during the years 2000 to 2002 in the project test site. It can be seen from this figure that delays caused by the shearer ranging arm do not fit an exponential distribution. The best-fit Weibull curve provides a fair representation.

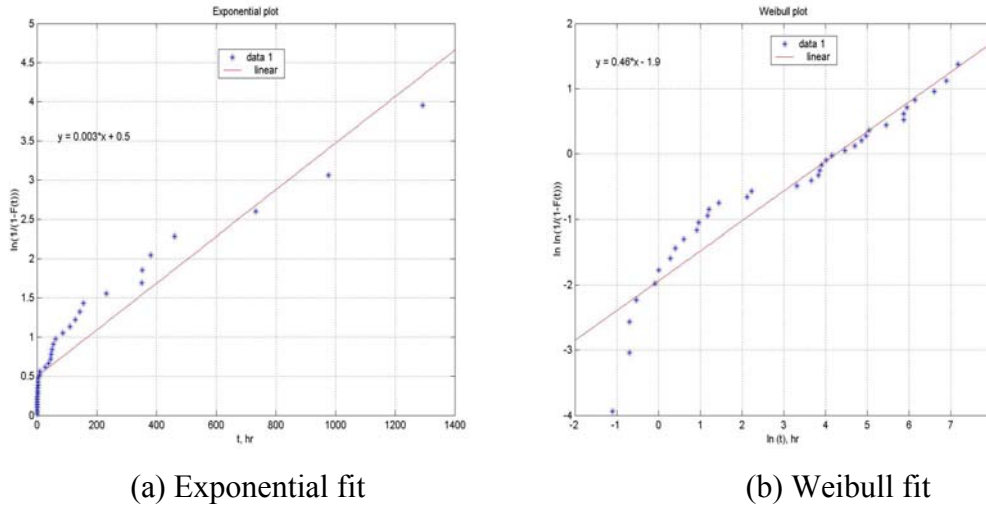


Figure 5 Probability plots for the failure data of shearer ranging arm

Figure 6 shows the probability plots of AFC chain failure data collected from 2000 to 2002 fit to both exponential and Weibull distributions. The failure data of AFC chain has a better fit to the Weibull distribution.

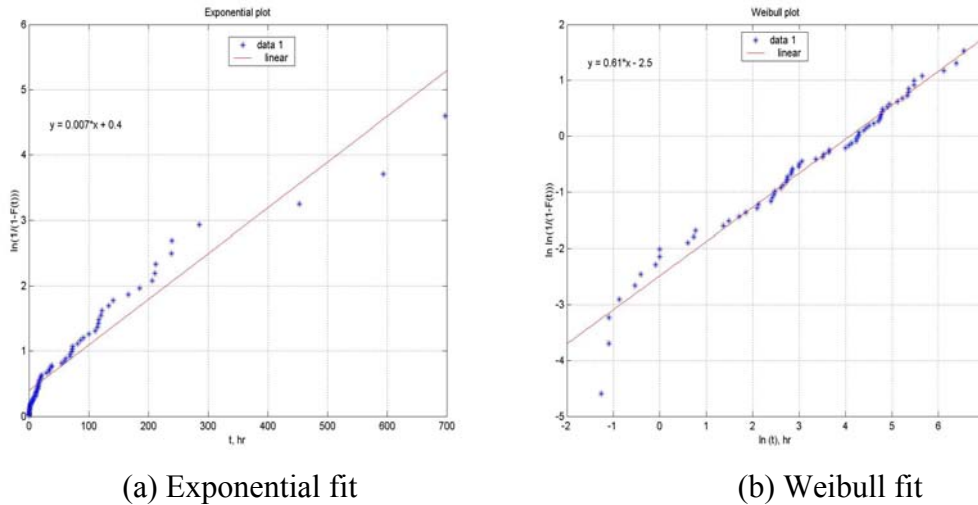


Figure 6 Probability plots for the failure data of AFC chain

Figure 7 shows the probability plots for failure data of the BSL chain collected from 2000 to 2002 to fit to exponential and Weibull distributions. The Weibull model offers a reasonable fit.

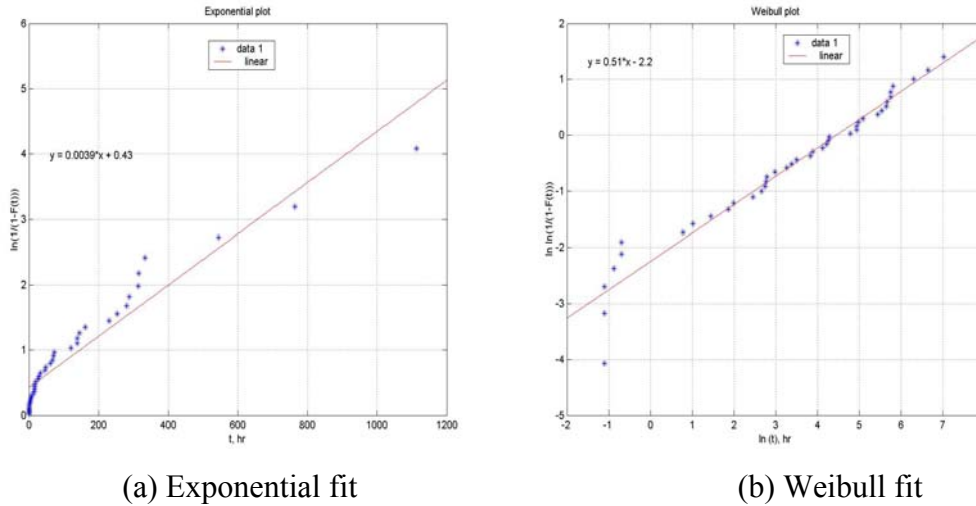


Figure 7 Probability plots for the failure data of BSL chain

All top 4 delays seem to fit Weibull distributions but with decreasing failure rate. This means the failure is less likely to occur as time progresses. Due to the decreasing failure rate of the Weibull distribution, it can be argued that preventative maintenance based on fixed replacement intervals would not help avoid these faults. With failure probability distributions following these or similar patterns, rigorous PM programs are not appropriate.

#### *Findings of the AFC simulation*

Two different AFC lengths were simulated and some results are presented in this section.

Figure 8 shows the motor power required to drive a 250m and 400m AFC. The power requirement for the 400m AFC is about 1.7 times that for the 250m AFC. The fluctuation of power is also significantly higher for the 400m AFC at the same chain pretension.



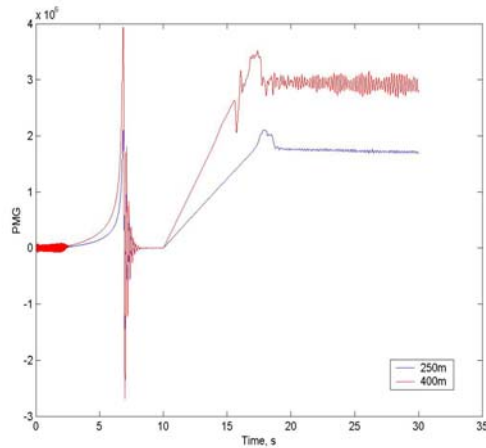


Fig. 8 Total motor power – 250m and 400m

The fluctuation of the sprocket torque for the 250m and 400m AFC is shown in Figure 9. The 400m AFC shows not only higher fluctuation torque but also richer frequency content — more peaks on the frequency-domain plot as shown in Figure 10.

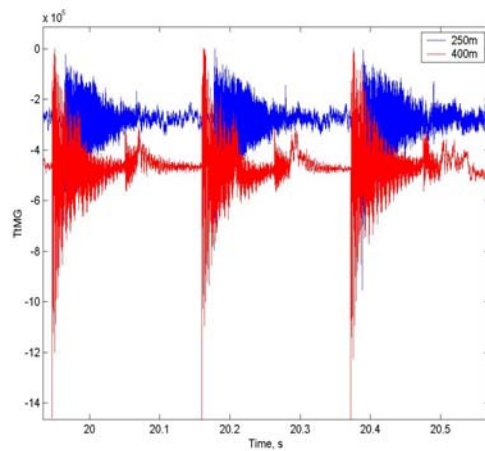


Fig. 9 AFC sprocket torque

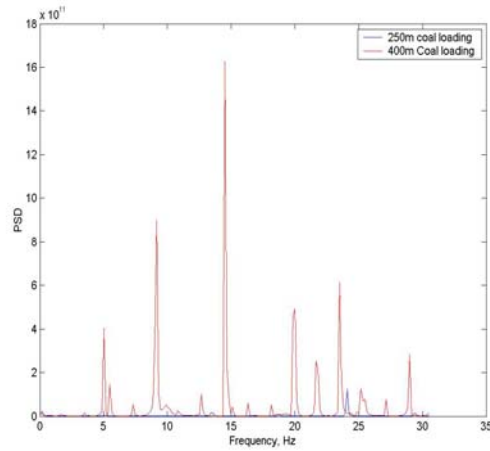
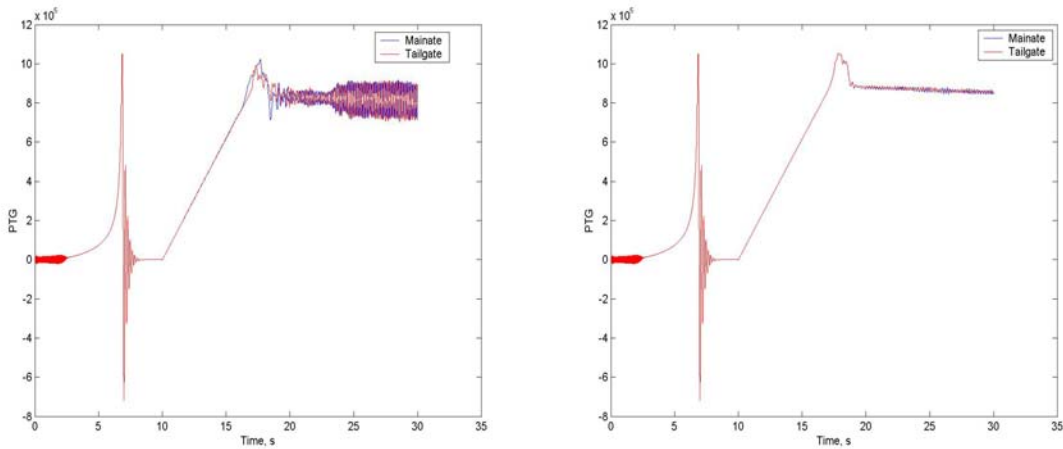


Fig. 10 Frequency analysis of main gate sprocket torque for 250m and 400m

Proper chain pretension is needed to prolong chain life and to minimize the risk of chain blockage due to slack. Figure 11 shows the power consumption with and without chain pretension. It can be seen that the motor power without pretension fluctuates more than the motor power with 30t pretension. The same conclusion can be drawn from the plot of sprocket torque as shown in Figure 12.



(a) No pretension

(b) Pretension of 30 t

Fig. 11 Main and tail gate motor power

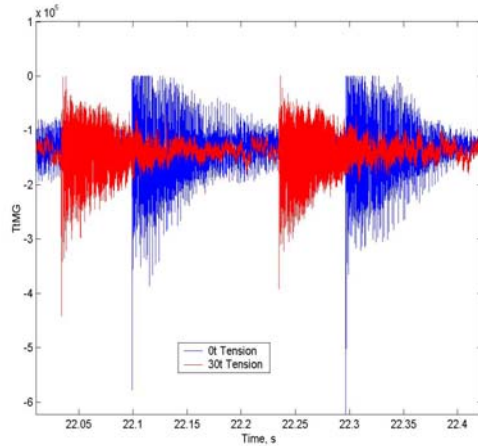


Fig.12 Main gate sprocket torque – zoomed

Figure 13 compares the chain speed at the main gate sprocket to study the pretension effect. When there is no chain pretension, the speed of the chain is close to zero after its disengagement from the sprocket. This creates significant slack near the main gate sprocket. The slack chain near the main gate is dangerous since it could interact with the BSL chain and cause the chain to break. A pretension of 30t is predicted to remove the slack as shown in Fig 13b.

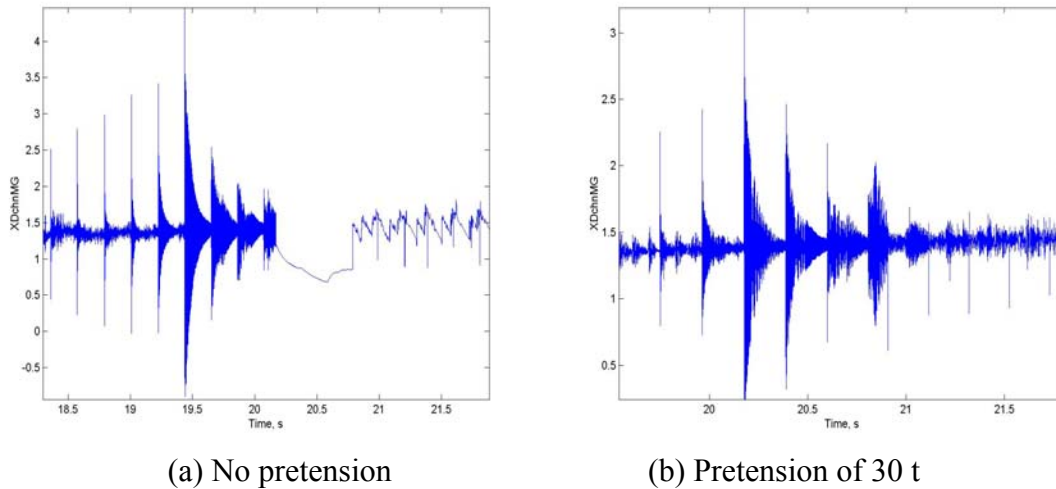


Fig 13. Velocity of the chain cross the sprocket

Figures 14 shows the variation of chain tension along the face. It can be seen from the tension distribution that the fluctuation of tension is smaller on the top deck due to the damping effect of coal loading. The power sharing of the main gate and tail gate motors can also be identified from the tension on the bottom deck chain.

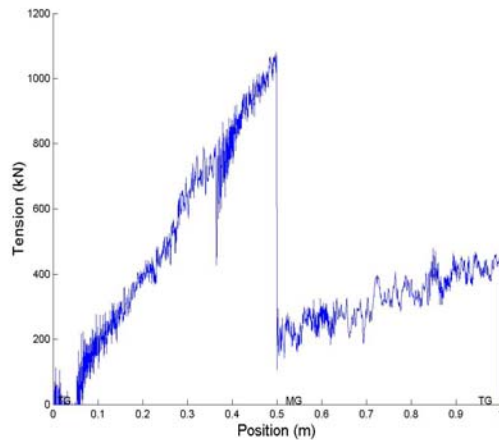


Fig14 Chain Tension along AFC length

## Summary

The overall objective of the Smart Longwalls Project is to achieve a significant increase in longwall productivity by improving the reliability of face equipment.

The benefits to the longwall industry are:

- A significant increase in longwall productivity
- Increased safety
- Longer useful life of expensive items
- Improved operating performance
- A comprehensive database
- A list of areas where one-off changes must be made to design
- Optimum PM activities

## References

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