A MAINTENANCE REVOLUTION

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discuss real-time condition monitoring for mobile mine equipment.

Machine condition monitoring (CM) is a vital tool for ensuring high asset reliability and plant availability in the ongoing revolution of modern plant maintenance strategies. However, the mining industry has lagged in the uptake of this methodology. Real-time condition monitoring (RTCM) overcomes the limitations of conventional CM and plays a key role in the maintenance and reliability of mobile mine equipment.

The evolution of CM

CM can be traced back to the roots of understanding equipment failure and the maintenance strategies that evolved to deal with these failures. The earliest and most basic maintenance strategy was breakdown maintenance. In this strategy, assets ran until they failed or no longer performed their designed functions. Teams would then make costly repairs, resulting in excessive downtime and lost production, before returning these assets to service.

The subsequent methodology, preventive maintenance, required teams to perform maintenance tasks on a timed basis to avoid failures related to the asset's age. Equipment was serviced on a fixed time schedule: maintenance personnel replaced subsystems or components when estimated service life had been reached. However, service life, calculated by OEMs, was overly conservative. The costs associated with this strategy are high and laden with repeated downtime.

CM techniques developed significantly over the last three decades as improved technology and data processors became available. The most commonly used tools in CM include, but are not limited to, the following:

- Oil analysis.
- Wear debris analysis (tribology).
- Vibration analysis.
- Infrared thermography.
- Ultrasound.
- Radiography.
- Non-destructive testing.
- Onboard / online health monitoring.

These tools work to detect degradation or symptoms of degradation in operating assets. They are integral to reliability centred maintenance (RCM) programmes and essential for detecting and preventing recurring failures.

The P-F interval

For successful CM, maintenance teams must have enough time and resources after detecting an impending failure to effectively perform corrective action on the asset. Equipment has similar behaviours and responses throughout machine life, even when failing. When deterioration begins (a factor that may be random in terms of service life), equipment undergoes a reduction in the ability to fulfill its intended function. At some point (P), approaching failure is detectable through inspection or other CM techniques. Unless addressed and dealt with, performance levels can deteriorate to a point where the asset no longer performs at its demand level (this is called 'functional failure', F).

The shape of the P-F curve (Figure 1) and the time between potential failure and functional failure (the P-F interval) will vary depending on a number of factors, such as asset type, duty cycle and failure mode. Constant failure modes for the same asset can exhibit different curves based on the operating context: this is especially relevant to mobile equipment (i.e. trucks and shovels) that experience highly variable duty cycles.

Figure 2 illustrates an extreme case where a CM test (t1) takes place just before potential failure. Before the next test (t2), sufficient time must be allocated to conduct planning and scheduling before asset failure can occur. Production loss resulting from not running the asset is then minimised, and an optimal maintenance plan can be made,

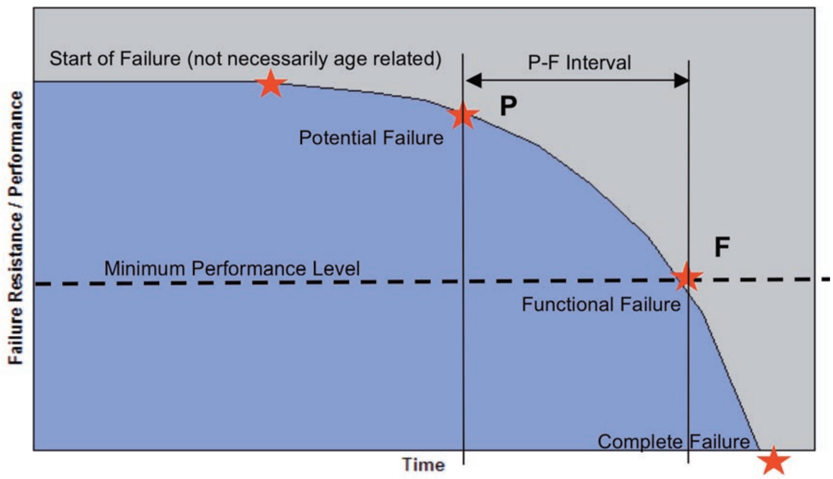

Figure 1. The P-F curve. (The commonly used industry P/F chart explains potential vs. actual failure.)

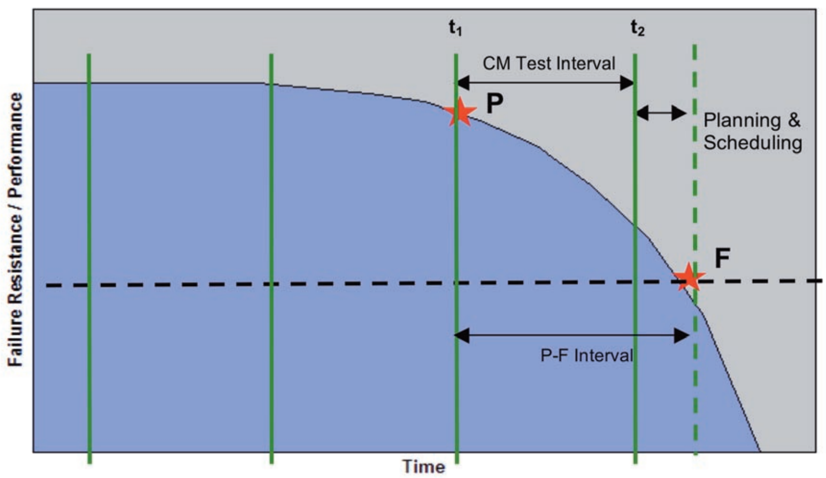

Figure 2. Sizing the CM test interval. (The commonly used industry P/F chart explains potential vs. actual failure.)

components procured and scheduling performed.

Planning and scheduling can take several days, especially when standard job plans are not available; however, if the P-F interval is not long enough, it can result in very short, impractical CM testing. If the asset is critical, the CM test interval should be selected so that maintenance can shut down the asset well in advance of functional or complete failure.

If the P-F interval is too short to allow a practical CM test frequency that would provide sufficient warning, teams must allow the asset to run to failure or perform a re-design of the system. The biggest challenge in mobile mine equipment is reliably detecting potential failure (point P) considering the variability of the operating context.

RTCM and mobile mine equipment

RTCM is defined as the ability to measure and perform CM in real-time. Data transfer latency is measured in seconds (not milliseconds as in some 'real-time' process control applications). The recent advent of RTCM in the mining market has created significant opportunities for savings and enhanced safety. These systems introduce the ability to alert maintenance and operations of abnormal conditions: alarms are triggered when monitored parameters exceed OEM manufacturer or user defined (UDF) thresholds, or when equipment is operating in an undesired manner. Sites can programme alarms to detect simple instantaneous threshold violations or more complicated, rapid increase violations. Such events are then extrapolated to predict potential violations that foreshadow failures. Conditions relating to operating context can be applied to UDF alarms for validation.

RTCM helps solve the dilemma of choosing appropriate CM test intervals. When properly configured, OEM and UDF alarms detect potential failures for many failure modes. The remaining requirement? Sufficient time to plan and schedule corrective work or, at the very least, to shut down equipment.

At present, examples of RTCM applications for mobile mine equipment are limited. While there is a growing number of onboard health monitoring systems for modern equipment, these require a physical connection to download data and use proprietary software for data manipulation. This results in non-real-time data (periodic data capture) and, sometimes, inconsistent data handling.

The MineCare® maintenance management solution from Modular Mining Systems Inc. links onboard health monitoring across disparate OEMs and third–parties. This link – connecting communications infrastructures and central software applications supported by mine management systems – provides a true RTCM solution. Such systems have proven their mettle in some of the most remote mining operations, saving thousands of dollars on maintenance costs around the globe.

The MineCare system has saved many customers downtime through RTCM. Two specific examples are detailed below.

Differential turbo exhaust temperatures

One site observed a significant difference in turbo exhaust temperature on a large haul truck. The right turbo exhaust temperature was higher than the left, suggesting that the left turbo was in failure and the right bank was working harder to meet the power demand. Corrective action was planned and scheduled to replace the turbo before complete failure occurred. While down, the covers were also removed from the right cylinders, revealing several cylinders that were experiencing partial ring failure. The rings were replaced and the truck was down for only eight hours. RTCM prevented a costly engine/turbo repair and several days of downtime.

Low oil pressure alarm

RTCM has also reclassified alarm priority for low oil pressure. In this case, the OEM classified a plugged engine filter as a low level alarm (meaning it would not display to central system attendants or operators) because the filter went into bypass and the engine still received oil.

Reclassifying the alarm as critical, the site began detecting plugged filter alarms for one of the trucks. In order to measure the crankcase pressure, which was very high, the attendant used the system to remotely connect to the unit in real-time. The filter was plugged with metal caused by partial failure of several piston rings. The truck was shut down for ring repair and returned to service in a timely manner. This RTCM event saved critical engine failure, downtime and production loss.

RTCM detects potential failures before they are noticed by operators or inspection methods. This allows time to plan and schedule corrective actions, or to at least stop the asset before significant or catastrophic damage is done. By combining RTCM alarms with mitigating processes, failures can be effectively eliminated.

Conclusion

Over the years, mining has incorporated various maintenance philosophies as they have evolved from breakdown maintenance and preventive maintenance to real-time maintenance. With a better understanding of failure modes and the advent of CM, overall reliability of equipment and effectiveness of maintenance has improved substantially. RTCM allows for the detection of potential failures, overcoming the constraint of short P-F intervals that make CM tests impractical.

RTCM holds huge potential for managing asset maintenance, and it is particularly beneficial for mobile mining equipment. Users no longer have to shut down equipment to board it and download aged data; removing this download step increases productivity. Additionally, this augments safety by eliminating the need to physically visit various equipment fleets and onboard systems. RTCM for mobile equipment affords increased reliability and uptime, more effective use of maintenance resources, and – most importantly – enhanced safety and production.