**Coal Mine in Southern U.S. Client Story**

**Recurring Slope Belt Drive Failures**

**Problem Summary:**

During the beginning of 2012 the mine had experienced several unscheduled minor outages that were a result of the mines’ slope belt drive equipment components failing in operation. These minor failures were taken care of in a relatively short amount of time and the slope belt was put back in operation after experiencing only short amounts of downtime.

On April 6, 2012 a more significant failure occurred; i.e., the mines’ Slope Belt South Gear Box experienced catastrophic failure of both the Drive Shaft and Coupling. As a result the North Gear Box was coupled to the Drive System and started on April 7, 2012. After 37 minutes of operations the Coupling Side Input Shaft Bearing failed catastrophically. The North Side Gear Box had recently (about 4 months prior to the incident) been rebuilt and commissioned at the manufacturers’ facility. The input shaft was removed from the gearbox and the bearing was changed out at the Machine Shop. The system was re-started on Friday, April 13, 2012.

Due to the unexpected nature and unacceptable number of these failures it was determined by the Corporate Reliability Group that a formal PROACT® Root Cause Analysis be performed to investigate the failures and uncover the true root cause(s) of these significant events.

During the analysis on April 30, 2012 another failure occurred on the TPKL to Reducer Grid-Coupling of the Slope Belt Drive. This related failure was also included in this analysis.

**The Financial Loss:**

The loss due to repair costs and downtime was estimated to be just over $3,000,000 for these recurring unexplained failures.
Findings:

The PROACT® Root Cause Analysis System was utilized and the RCA team determined that:

Recurring failures of the Slope Drive System could be attributed to the physical failure of drive components caused by design related issues, lack of proper basic care, poor maintenance practices and operating procedures, as well as inadequate documentation of past issues associated with the reliability of this extremely important system.

The shaft failure of April 6th was a result of the Backstop on the South Gear Box incorrectly engaging under a high-torque situation. The physical evidence revealed that the backstop was already in a failed state due to earlier over-torque applications. Note that the previous damage to the Backstop was a result of the failure of the Parking Brake to engage as designed. This in conjunction with rapid starts after immediate shutdowns caused the spags of the Backstop to become worn and hang up within the Backstop cage. The fact that mine personnel recover from unexpected trips in operations without Standard Operating Procedures, and a general lack of understanding of the operational characteristics of the system itself, was also a major cause of the incident.

The North Box High-Speed Shaft Bearing failure that occurred on April 7th was caused by insufficient clearances in the bearing fit. Insufficient clearance was exasperated by starting the system without proper warm up of the lube oil package. This resulted in uneven heating across the bearing and eventually catastrophic failure to the bearing cage and subsequent destruction and lockup of the rolling elements. In addition, lube oil temperatures were not included as a permissive in the original PLC design. Although there are permissive for oil flow and pressure for startup, a lack of the recognition of the importance of lube temperature (and Standard Operating Procedures) at startup, also can be attributed to this failure.

The Coupling Failure (between the TPKL and Reducer) that occurred the evening of April 30th was a result of utilizing mismatched coupling components and inadequate greasing during the April 12th rebuild, and the re-installation of damaged grids during the April 29th repair. Since there are no check sheets, or procedures, for making these types of repairs, coupled with a general lack of application of good maintenance practices, unexpected component failures can be expected.
Recommendations:

1. In conjunction with the implementation of the current lube sampling program, have the current lubrication suppliers provide training to plant personnel and contractors on lubrication types, systems, uses, limitations, etc. Vendors that supply equipment with lube systems as part of the package should also educate plant personnel on their specific operations, requirements and limitations.
2. Hold toolbox meetings to stress the importance of starting plant systems at the proper temperatures, pressures and flow rates.
4. Establish a culture of Reliability and set up a Reliability Group at the mine to put in place and maintain this culture.
5. Replace the backstop on the south box. Implementation of the new re-design with the backstop on the head pulley will negate the need for a parking brake and significantly mitigate or eliminate failure that could occur with the backstop being installed on the high-speed shaft.
6. Move the back stop from the high speed input shaft to the conveyor head-pulley shaft and perform a MOC on the design change. Note that moving the backstop to the head-pulley shaft should negate the need for the parking brake.
7. Utilize the OEM manuals to properly develop Maintenance Standard Task(s) (MST's) for Slope Belt Drive Components.
8. Have engineering redesign the configuration of gearbox to allow for movement of the backstop from its current location to head-pulley shaft.
9. Review the TPKL Installation and Operating Manual Type D (Double) and create and implement Maintenance Standard Task(s) (MST's) based on the manufacturers requirements and recommendations.
10. Using OEM manuals and instructions develop the appropriate Standard Jobs for all rebuilds including Checklist and Hold Points (key points that need to be checked and initialed as completely corrected).
11. Using OEM documentation develop inspection programs for slope belt drive components taking into consideration operations outside of those recommended by the OEM.
12. Write an SOP for startup of the slope belt drive.
13. Utilize the OEM manuals to develop Job Orders for the operations of slope belt drives.
14. Establish a document control program to ensure that all equipment manuals match actual plant equipment.
15. Utilize the OEM manuals and Maintenance/Operations Process and Standards (MPS) to properly develop Maintenance Standard Tasks (MST) for Slope Belt Drive Components.
16. Set a permissive in the PLC to accommodate the OEM’s requirements for a minimum 80°F lube temperature prior to start up. Note that the current air to oil heat exchanger appears to be so efficient that oil temp may be difficult to maintain during cooling fan off periods.
17. Replace all grids in the slope belt couplings with Dodge Grids to match couplings halves.

18. Perform Engineering model of the existing building structure and add additional support to the structure as required. Note that with the recent proper alignment and installation of drive belt components the building is now seeing a remarkable reduction in vibration levels.

19. In order to mitigate the possibility of closing the clearance to the point where oil flow is restricted in the high-speed bearing, replace the Standard Fit Bearing with a C-3 fit and have startup personnel visually check lube temperature gages to make sure that it is at a minimum of 80 degrees F prior to starting the equipment.

20. Per OEM’s recommendations coupling hubs should be hand packed prior to the installation of grids (or outer couplings if gear type). These types of couplings should be lubricated with Mobile XTC as recommended by the Corporate Reliability Group. Although this should be used across the site it should be noted that this type of grease cannot be mixed with any other type or brand and other couplings must be thoroughly cleaned prior to its use. Procedures for the use of XTC grease are available from the Corporate Reliability Group.

21. Use Nord Lock Washers and Max Bolts (with built-in strain gages) for the outer race bolt covers of the backstop and routinely verify bolt tightness by visual examination.

Return on Investment:

Although no formal quantitative analysis has been done to determine the actual financial benefit of this analysis, the lessons learned from the analysis and the implementation of the above recommendations to mine equipment plant wide has resulted in a substantial reduction in downtime due to equipment failure.
Overheated Coupling
Coupling Side Failed Bearing
North Side Bearing Failure
Float Side Shaft Fracture