Increased production systems effectiveness through condition monitoring and prognostics

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Optimum maintenance of mill liners

Mining industries uses heavy-duty equipment that must work around the clock in highly abrasive environments. Autogenous (AG) mills used in the mining industry and ore dressing plants are examples of major bottlenecks in the context of downtime concerning the production economy. Rubber liners inside the mill are critical component in the context of shell protection and ore grinding. Replacement and inspections of the mill liners are major factors regarding mill stoppages and corresponding production losses due to mill stoppage. The present research presents the usefulness of Life Cycle Cost (LCC) and Life Cycle Profit (LCP) analyses for the mill liners of the mining industries and demonstrates decision models for effective maintenance planning. The research is presented in two parts.

Part 1 deals with optimum replacement interval for group replacement of mill liners. It briefly describes the interrelation between maintenance and process parameters. The study shows the impact of maintenance strategies on grinding process which leads to significant savings of the mill. The physical explanation of each parameter (power, metal output, liner wear, inspection policy, ore density, torque etc) is provided to give in depth picture of the effect of maintenance decisions on the process economy. Based on the knowledge and interaction between these parameters, a mathematical model for LCP has been developed for optimizing optimum replacement interval of group of mill liners. The present research simulated the LCP model for different ore types and optimum replacement interval for the replacement of mill liners is obtained. The results of this study observed significant savings when suggested maintenance policy is introduced. See Figure 1

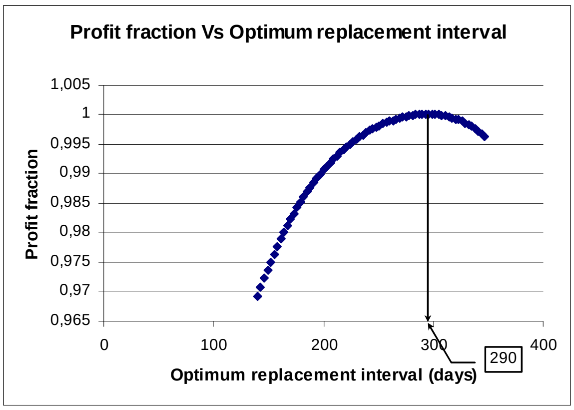

Figure 1. *Profit fraction versus optimum replacement interval*

Part 2 deals with detailed analysis of mill downtime as it focused at mill stops due to major and minor replacement of mill liners. The reasons of multiple stops are due to different life cycle period of different parts of mill liners. This minor stop not only leads to production losses during replacement but also leads to losses which occur during start up time. The replacement of all parts of the mill liners all together is not possible due to technical and economical reasons. The aim of this study is to minimize the LCC by optimizing the grouping for joint replacement and wear life period of different parts of mill liners. The optimized maintenance decisions are based on the tradeoff analysis between monetary savings by reduction of mill stops and the cost incurred for improving the life of the part of the mill liners. Dynamic programming has been used to determine the life cycle cost (LCC) for each feasible scenario for maintenance scheduling for various life improvements of mill liners parts. The scenario with minimum LCC provides the optimum grouping for joint replacement and necessary life improvement of different parts of mill liners. The result shows that an optimum life improvement can further reduce the LCC. A demonstrator has been developed for making these cost effective maintenance decisions.

Condition monitoring of fatigue cracks in rotating mining mills

Infrared thermography and fatigue damage sensors have been investigated as non destructive testing methods for health monitoring of rotating mining mills. The idea of the thermography method is to monitor the thermal differences on the mill surface with thermal camera in order to detect and maintain cracks and other material damage in the mill material. Figure 2 show thermal images taken during operation on a cracked mill head. The fatigue damage sensors are attached to the tips of a fatigue crack and measure its propagation. The sensors consist of thin conductive wires which break one after the other as the crack propagates through the sensor, see Figure 3. To test the usefulness of the methods, real life measurements with IR-camera and fatigue damage sensors have been performed on the mining mills at LKAB dressing plants. Preliminary results indicate that infrared thermography is a fast, easy and relatively cheap inspection method which can find and monitor fatigue cracks and material damage in rotating mining mills. The fatigue damage sensors measure the real crack propagation but are not easy to place duo to wiring and connectivity setup. The large and fast propagating cracks together with the harsh mining environment make the method not suitable for monitoring of mills

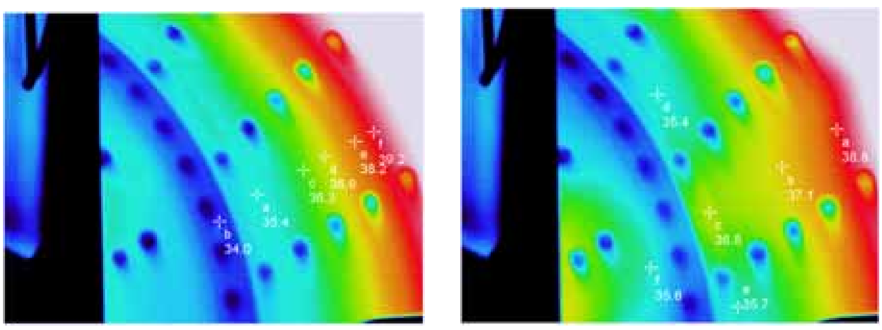

Figure 2. *Thermal images of a mill head, crack free portion to the left and cracked portion to the right*

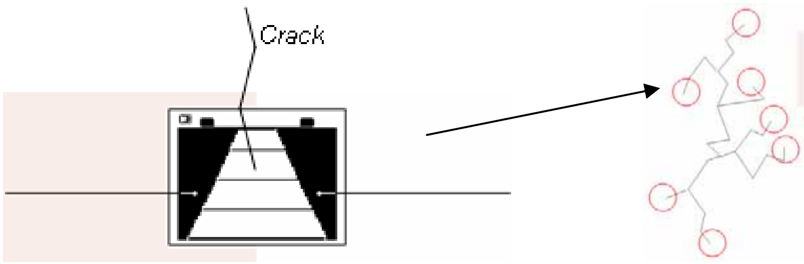

Figure 3. *Fatigue damage sensor*

Keywords: *Maintenance decisions; Mill liners; Life Cycle Cost (LCC);Life Cycle Profit (LCP); Production economy; Optimization; Replacement decision, Wear measurement device, fatigue cracks, infrared thermography, condition monitoring*