Improved Technologies for Mill Roll Inspection

1. Introduction

In the fall of 2002, a revolutionary method by which to inspect mill rolls was introduced by Innerspec Technologies to the metal producing industry. The Rollmate® represented an ultrasonic approach designed to overcome the inadequacies of existing inspection technologies while maximizing return on investment. Since then, a number of numerous improvements have been made possible and the latest Rollmate (Generation 3) provides the most comprehensive tool available for the inspection of all types of mill rolls. This paper provides an overview of mill roll inspection technology and the effects that various inspection technologies can have on the efficiency and costs associated with operating a roll shop. It will also highlight how the Rollmate® provides alternatives otherwise not available.

2. Mill Roll Inspection

The inspection of mill rolls is a requirement in the operation of a safe, efficient mill. Work rolls used in steel production are susceptible to work hardening and accumulation of residual surface stresses leading to the production of cracks. If not completely removed prior to the reintroduction of the roll into service, the cracks can grow and result in sudden catastrophic failures, or spalling. In the aluminum industry, caster rolls are also predisposed to cracking, however the mechanism is more related to fatigue cracking as a result of thermal cycling. In both cases, rolls are periodically removed from service and sent to grind machining that mechanically remove the outer layer of material where cracks form and propagate.

3. Crack Detection

The profitability of a plant can be affected on the efficiency and effectiveness of the roll shop and its method of roll inspection. First, the system deployed must be capable of reliably detecting “micro-cracks”. Micro-cracks are small fractures that break the surface of a roll and act as stress risers. If these flaws are not completely removed prior to reintroducing the roll back into the mill, they can quickly grow to a size resulting in a spall condition. A work roll that fails in service leads to damaged product, it can also damage neighboring rolls and requires the line to shut down for hours while material and rolls are removed. Similarly, a caster roll with existing cracks can introduce small imperfections in the product that can easily go undetected until a significant amount is produced. Therefore, it is important for the plant to employ the most effective and reliable crack detection technique available.

Prior to the introduction of the Rollmate®, rolls were inspected exclusively using Eddy Current techniques, Ultrasonic Surface Wave (Rayleigh Wave) technique, or Dye Penetrant Testing. Each of the currently used technologies has problems and limitations that are not necessarily related to a specific system model, but it is characteristic of the method itself. For example, Eddy Current methods can offer relatively good sensitivity to surface cracks, but have a problem with false calls due to localized residual magnetization and other conditions of the roll. Roll magnetization occurs when the roll temperature is elevated during use in an environment where stray magnetic fields created by high current devices (such as motors) are common. Localized magnetic fields effectively can both mask or create a false call condition making the results unreliable.

Another critical limitation of these systems is that eddy currents cannot be generated in materials with low conductivity such as rolls with high chrome content thus they are ineffective for inspection of caster rolls and some work rolls.

Finally, eddy currents, ultrasonic surface waves, and Dye Penetrant are all limited to surface or very-near surface defects.

Roll inspection using the Rollmate® is performed by employing uniquely designed ultrasonic sensors that generate high frequency sound that is sensitive to surface defects without being effected by surface contamination, such as grinding fluid, water, etc. Many roll inspection systems have now added ultrasound in combination with eddy current, with the ultrasonic inspection limited to defects with reflectors parallel to the roll surface.

The patented sensor design on the Rollmate® produces a surface-skimming wave that is commonly used throughout the nuclear industry for crack detection in piping welds and other applications. The sensor design facilitates the detection of micro-cracks smaller than that possible using any commercially available equipment currently on the market. All other techniques, including Die Penetrant Testing, have the ability to detect cracks of 2-3mm in length. Cracks with lengths down to 1mm are easily detected using the Rollmate® system making it the most sensitive crack detection system available. The probability of missing a micro crack large enough to result in a catastrophic roll failure and mill stoppage, with all its associated costs, is almost nil.

Another critical advantage of the Rollmate® is the ability to use the same transducer assembly to inspect deep inside the roll for defects, at any orientation. While the surface skimming wave can penetrate down to 2mm in the roll, the deeper modes can penetrate and detect defects down to 50mm or more into the roll. Soft/bruised areas, and shell thickness & core-shell disbond on shelled rolls, can also be inspected without the need to change inspection sensors.

4. Roll Wastage

Mill rolls are a direct expense to the mill. The grinding process is a costly procedure considering that every pass reduces the life of the roll. The cost of a new or refurbished roll can run from $100K to $500K per roll. Caster roll shells with less than 4" of usable life are equally expensive. Although an inspection system cannot reduce the number of grinding passes over the life of a roll, it can control the number of grinding passes per production cycle. Off-line inspection systems require the operator to grind a predetermined number of passes prior to an inspection. This is performed over and over until the roll inspects defect free. Although effective, it commonly results in many more grinding passes then actually needed to clean the roll of all defects.

The most efficient method is real-time inspection while grinding. This feature provides the operator with continuous roll status so that grinding can cease as soon as the roll is defect free. The only two methods available are Eddy Current and the Rollmate® ultrasonic technique. Although available, eddy current inspection has difficulty with real-time inspection due to its sensitivity to lift-off. Slight lift-off variations of an eddy current probe can result in significant reduction is sensitivity. The lodging of grinding slurry particles between the probe and the roll surface can lift the probe and cause a localized reduction in sensitivity. In contrast, the Rollmate® ultrasonic transducers are not sensitive to lift-off variations of this magnitude. In addition, the Rollmate® uses couplant ports that force filtered fluid between the transducer and the roll which flushes out and prevents and grinding slurry from entering the crevice between the transducer and the roll surface. Use of the Rollmate® in this real-time mode, maximizes roll life by minimizing the number of grinding passes performed for each use cycle. When factoring the number of rolls associated with a mill and the resulting life extension earned for each roll, just the material costs savings can be high enough to justify the equipment investment in less than a year.

5. Equipment Utilization

Inspection efficiency is directly linked to grinder utilization. The more efficient the process the fewer grinders that are needed to assure interruption free operation of the mill. The most inefficient roll inspection method commonly used is found in the aluminum industry. The liquid penetrant method requires about two hours per inspection cycle and is very labor intensive. Many automated systems require that the entire scan of a roll be complete prior to displaying data. This process also is inefficient since the detection of one crack at the beginning of a scan could be enough to require a more grinding. Therefore, to assure maximum scan efficiency, the inspection system must be capable of displaying data as it is being collected. This feature informs the operator that a crack is present as soon as it is detected so that the inspection can be halted and further grinding commenced. The Rollmate® provides this inspection feature whether during or following a grinding pass. The Rollmate® used in its real-time mode while grinding, provides the operator with the maximum possible grinder utilization since it eliminates any need for post grind inspection time.

In addition to this, each time a specific roll serial number is in the grinder, the previous inspections are reviewed and automated analysis determines the predicted life of the roll based on previous scans, and the condition of propagating internal defects.

6. Ease of Use

A commonly over looked characteristic of an inspection system is the overall complexity of the machine design and ease of use.

An inspection system should be designed roll shop operators can solve the majority of repair scenarios. For this to be possible, the system must be designed based on a modular component philosophy. Significant costs can be incurred when a roll shop is required to contract specialists to visit their site to perform system diagnostics and repairs. A modular based system containing plug-in components can be diagnosed and repaired remotely where replacement parts are shipped to the customer. The Rollmate® is such a system where major components are of plug-in design that can be quickly replaced. In addition, the Rollmate® is equipped with diagnostic software to notify factory personnel and Innerspec engineers when a problem is detected.

Every automated roll inspection system requires calibration to assure sufficient sensitivity during data collection. The process involved can be costly where periodic visits from the manufacturer are involved. Eddy current system calibration can be very involved since the probes are sensitive to material type and probe wear (lift-off). In this case, calibration is required often to offset variations in lift-off due to probe wear, and can involve the use of several different calibration blocks that represent variations in metallurgical composition of different roll types. In contrast, the Rollmate® can automatically self-calibration simply by positioning the transducer on top of the roll. The process is quick (1 minute) having minimal effect on productivity.

The most important aspect of inspection hardware is the presentation and ease of interpretation of the data. Automated roll inspection equipment varies greatly in the format in which data is displayed. Eddy current systems have data presentations that vary greatly. System outputs range from strip chart records to color blocks maps where each block represents a region of a roll. The Rollmate® is capable of producing an image that can be quickly interpreted (the color is an indicator of a crack) but also clearly shows the shape, size and location of the defect. For more detailed information on the scan, individual displays are available for each type of defect. All data is recorded for post analysis and easily output for roll database management.

8. Summary

A roll inspection system is not only a necessary safety tool in any modern rolling mill, but it can also have a significant influence in the economics of the whole operation.

Designed and manufactured exclusively by Innerspec Technologies, the Rollmate® is the most cost effective inspection tool designed to provide superior rates of return by.

- Increasing revenue through guaranteed crack-free rolls that will not damage the final product.
- Reducing costs in inspection time and roll material waste.
- Optimizing asset utilization in both the grinder and the rolling mill.