ESTABLISHING A COMPREHENSIVE PREDICTIVE MAINTENANCE PROGRAM IN A HIGH SPEED ROD MILL[1]

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Abstract

Until the 1980's, Predictive Maintenance was not a readily accepted practice among many manufacturing firms. Seen as unreliable, unproven and unjustified, many companies chose to follow Preventive Maintenance practices or just allow their equipment to "Run-To-Breakdown". The past decade, however, has proven that the theory involved in Predictive Maintenance practices is truly applicable and can provide firms with a competitive advantage in the marketplace. Today, most companies realize the importance of designing and implementing a Predictive Maintenance program, and the debate is now over how to implement it and to what extent. The following sections highlight the physical and financial differences between each strategy.

Keywords: Predictive maintenance; Rod mill maintenance; High speed rod mill.

ESTABELECENDO UM PROGRAMA ABRANGENTE DE MANUTENÇÃO PREDITIVA EM LAMINADORES DE LONGOS DE ALTA VELOCIDADE

Resumo

Até os anos 80 os programas de manutenção preditiva não estavam completamente aceitos pela indústria. Vistos como não confiáveis, não comprováveis e injustificáveis, muitas empresas escolheram seguir práticas de manutenção preventivas ou simplesmente deixando seus equipamentos seguirem trabalhando até uma quebra. Na década passada entretanto foi provado que as teorias envolvidas nas práticas de manutenção preditiva são verdadeiramente aplicáveis e podem prover vantagens competitivas no mercado. Hoje, muitas empresas percebem a importância de projetar e implementar um programa de manutenção preditiva e os debates agora focam sobre como implementá-los e em qual extensão. Nas sessões seguintes frisaremos as diferenças físicas e financeiras entre cada estratégia.

Palavras-chave: Manutenção preditiva; Manutenção de laminadores de alta velocidade.

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REACTIVE MAINTENANCE, "RUN-TO-BREAKDOWN"

"Run-To-Breakdown" simply means that equipment is allowed to operate until an element of the system fails and the system can no longer operate effectively. This is the most costly maintenance strategy available due to excessive damage to equipment, increased consumption of spare parts, extended mill downtime and excessive energy costs. It is estimated that at least 2 percent of energy is consumed overcoming vibration. Run-to-Breakdown Maintenance programs have the highest impact on a firm's operating costs, due to low control on schedule of maintenance tasks and also the need of replacing valuable components such as housings, shafts, gears… instead of just bearings.

PREVENTIVE MAINTENANCE

Preventive Maintenance is the practice of periodically replacing machine and system components at scheduled intervals in anticipation of possible failures. In the 1950's, preventive maintenance was developed in an attempt to increase equipment life expectancy by performing repair (or replacement) prior to anticipated failure. Before Predictive Maintenance techniques were adopted, Morgan also practiced Preventive Maintenance. Morgan recommendation for rebuilding high speed equipment was every 4-5 years. This was based on theoretical bearing life.
Preventive maintenance techniques lead to two possible situations:

1. Premature failures will be undetected, increasing the probability that other critical components will be damaged.
2. Bearings will be changed before they are required. It is now understood that inappropriate time-scheduled maintenance often increases the risk of failure by reintroducing infant mortality to stable systems or introducing problems during the tear-down or rebuild processes.

PREDICTIVE MAINTENANCE

Predictive Maintenance (PDM) is the practice of using non-invasive techniques (known machine parameters) to predict the failure of a machine or system. The use of Preventive Maintenance led industry professionals to recognize that many failures give advance warning through changes of machine or system parameters, such as vibration and temperature. Predictive Maintenance programs are designed to identify and adapt to the failure modes for each machine or component. A successful predictive maintenance program will result in reduced spare parts inventory, fewer catastrophic failures, increased productivity, and more efficient and effective maintenance planning.
Predictive Maintenance is based on the practice of comparing the trend of measured machine parameters against known engineering limits and professional experience for the purpose of analyzing, detecting and correcting equipment problems before failure occurs. Examples of machine parameters include temperature, pressure, vibration, noise, and current, to name a few. By determining upper and lower control limits for each and trending them over time, the performance of equipment can be determined in the present and predicted for the future. Though simply described, the practice of predictive maintenance can be quite challenging. Machine parameters often change relative to time, environment and operating conditions, understanding the base line and analyzing parameter data requires experienced professionals.

Predictive Maintenance technologies include Vibration Monitoring, Oil Analysis, Thermography, Balancing of critical equipment, etc. Predictive Maintenance task are performed on-line; not requiring to stop or decrease production. These techniques provide an advance warning of problems. Therefore maintenance planning can be scheduled in advance and without disrupt to production. Trend analysis is a powerful tool to determine the state of machinery. Changes in trending trigger alarms that ensure the stable operation and condition of a rolling mill.
World Class high speed rod mills in today's global economy must operate with the following standards for success: a) Yield 96-97%, b) Utilization 85-90%, c) Rejections less than 1% and d) Cobble rates less than 0.4%. The key contribution of the Maintenance organization in any mill is to ensure that Mill Utilization is over the goal presented here.
The implementation of a comprehensive Predictive Maintenance program achieves outstanding results, significantly increasing mill utilization. There are many service providers to choose from, however only OEM's (Original Equipment Manufacturer) have the advantage of deep understanding of the equipment in the high speed rod mill. This knowledge makes the OEM the best partner for any mill maintenance group to jointly develop such a maintenance program. The proper combination of Predictive Maintenance Techniques, complemented with OEM periodic maintenance audits, OEM's lube system audits, OEM training, as well as a properly developed spare parts program deliver outstanding results in any high speed rod mill, ensuring that utilization is more than 85-90%.

Predictive Maintenance Benefits/Goals

The most important benefit of Predictive Maintenance is a significant increase in mill utilization, mainly due to the fact that machinery condition is known at all times, allowing repairs to be scheduled and avoiding production losses due to unplanned mill downtime.
Also maintenance costs are noticeably reduced as a result of efficient planning of Maintenance tasks, resulting in cost effective use of downtime, manpower, and spare parts inventory. Furthermore, unexpected catastrophic breakdowns are avoided and energy efficiency is improved.
The impact of predictive maintenance techniques go beyond benefits in maintenance and mill utilization. It also reduces stress on personnel and increases safety.
Proper Predictive Maintenance Techniques can detect almost any type of defect during the nucleation stage, thus allowing sufficient time to plan and perform necessary repairs, before damage reaches to higher levels compromising mill production. Morgan Predictive Services is fully dedicated to maximize mill utilization not only forecasting sources of trouble, but also providing all the support necessary to preserve all mechanical equipment in good condition including balancing of critical equipment, fast delivery of OEM parts, Field and technical Engineering support, Reconditioning services and on site training.

Vibration Data Collection

In order to ensure proper mill operation vibration data is acquired from critical mill equipment. Considering a generic Morgan rod and bar rolling mill layout, the following equipment is typically examined by Morgan Predictive Services:

- Furnace (Cross pusher drive, skid hydraulic pump)

- Descale Pump
- Roughing and Intermediate Mill: Primary drive motors & Gearboxes.

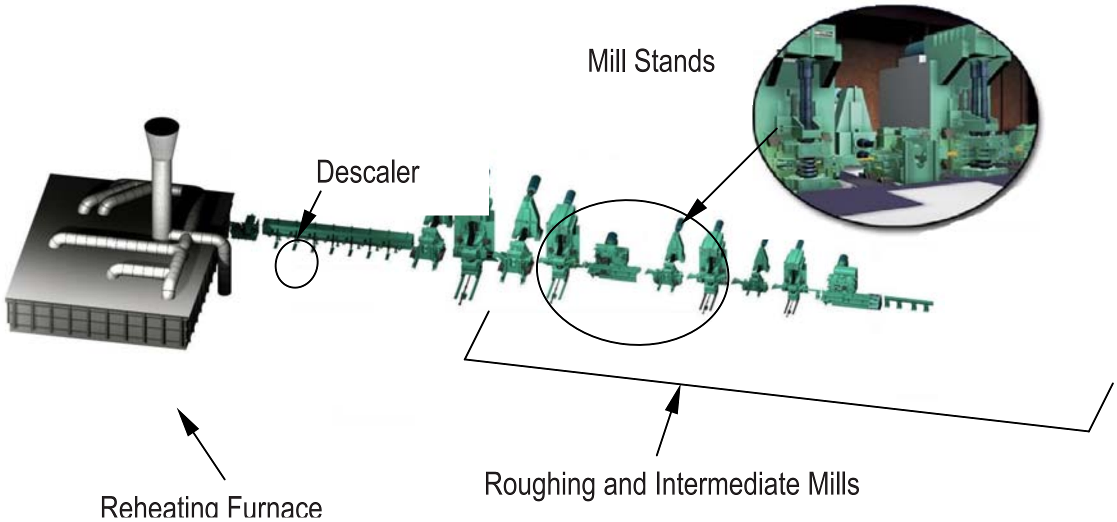

Figure 1. Roughing and Intermediate Mill Layout

- Pre-Finishing Mills: Motor and Drive Box
- No-Twist® Mills (NTM): Increaser, Motors and Rolling Stands
- Reducing/Sizing Mills (RSM): Motor, Drive Box and Roll Units
- Pinch Rolls Drive motor and gearbox
- Laying Heads[1]: Drive motor and gearbox. Periodic balancing required
- Stelmor Conveyor: Fans and Drive System
- Lubrication Pumps
- Water Pumps
- Hydraulic Pumps

[1] See detailed section in page 7

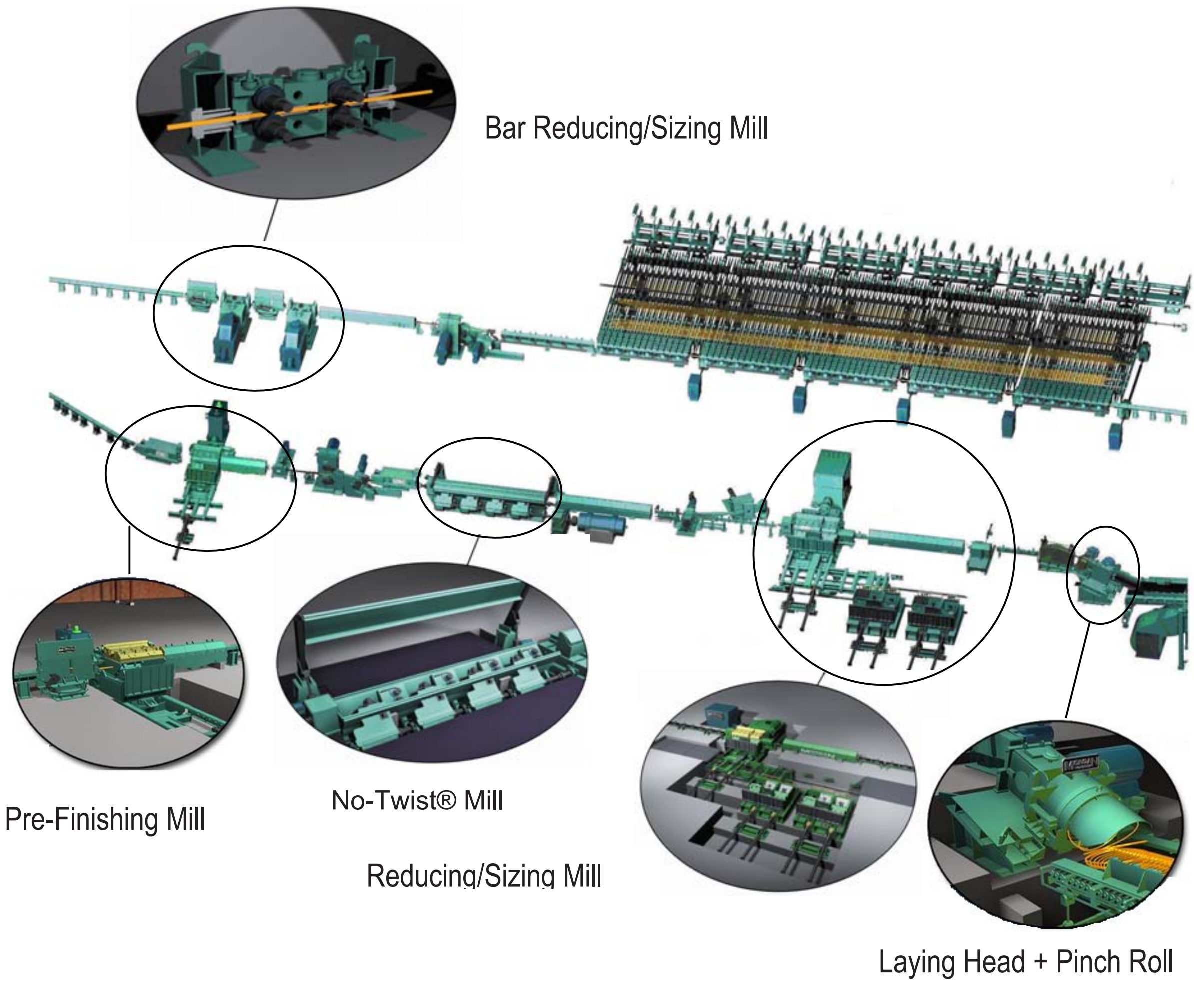

Figure 2. Bar and Rod Mill Layout .High Speed Equipment

There are basically two options available to acquire Vibration data, manual data collection and On-line System. Both systems can be combined and accessed through a private and secure internet accessed central database.

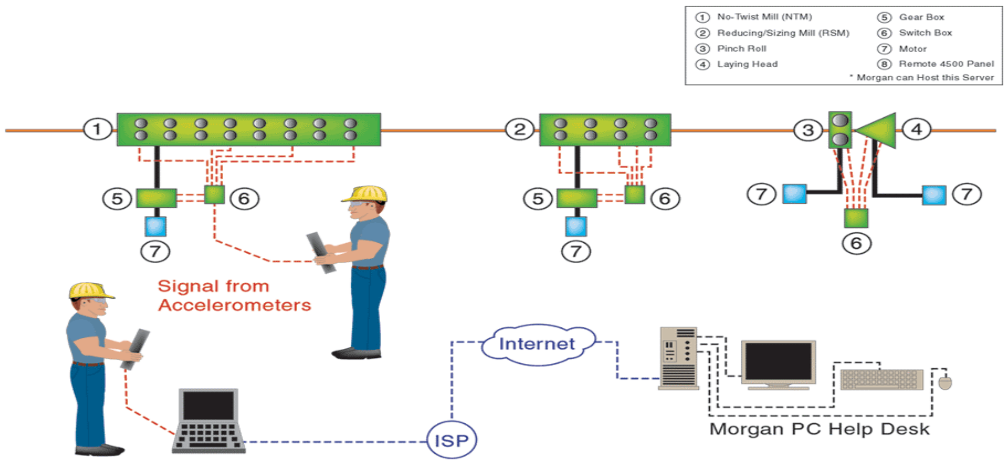

Figure 3. Manual Data Collection System

The first option, Manual Data Collection, vibration data is collected manually utilizing portable equipment by either Morgan Field Engineer or by internal mill personnel at the specified frequency, typically once per month or twice for high speed critical equipment. Data is stored in the Morgan data collector, extracted into a memory stick and sent via e-mail to Morgan Predictive Services team that will generate a report with valuable feedback and suggestions. A manual Data Collection monitoring program can be introduced at any stage of equipment life, at the startup of new equipment or introduced at any time for existing equipment are easy to operate and do not require complex training. This system provides an exceptionally cost effective solution with no irruption of mill operations.

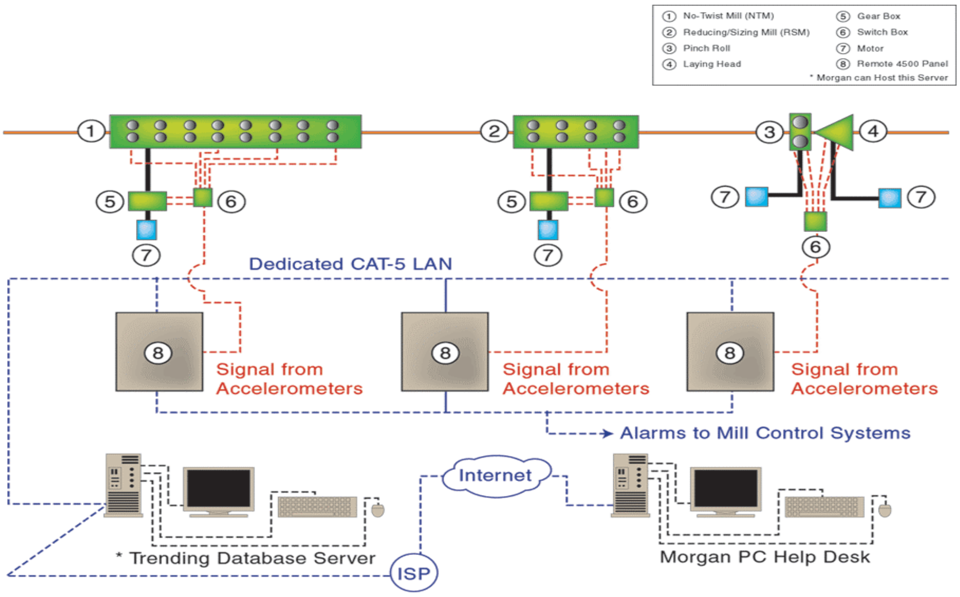

Figure 4. On-line Data Collection System

A more advanced alternative is the On-Line System, this system provides continuous surveillance and automated alarms that can be interlocked with Drives. Remote analysis for this service can also be provided. Compared to the manual data collection System, the On-Line System provides a higher level of support being; however is more costly and complex to operate.
The figure shown below differentiates the scenarios in which these two different monitoring strategies are more suitable. Small time to failure and high cost of lost production require on-line surveillance systems. On the other hand, use of periodic sampling is recommended when time to failure is moderate and cost of lost production is medium-high.

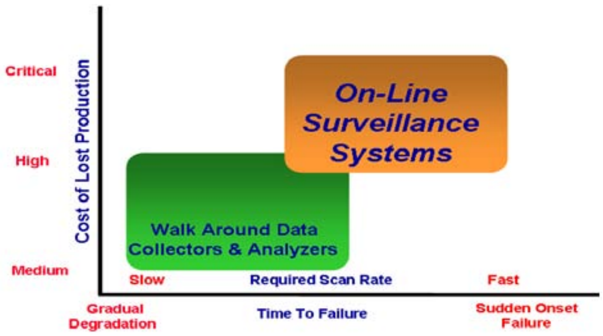

Figure 5. On-Line System vs. Manual Data Collection

Acceptance Limits

Knowledge of equipment is critical to set adequate acceptance limits for each component. Understanding of equipment design and historical operating characteristics are essential for good predictive maintenance operation.
Also it is necessary to establish base line levels that will identify correctable problems before they escalate. Base line levels are unique to each type of equipment, operating conditions, mill foundations, and environment.
One analysis tells current absolute situation. Historical trends compiled with equipment rebuild records will inform about relative equipment condition. This information is extremely valuable to predict equipment service life.
Historical trend data is initiated at Morgan's facilities before equipment start or continue full operation in rolling mills around the world. This information is also used to ensure the Morgan quality.
All this information and deep knowledge of the equipment allows Morgan Predictive Services to generate valuable monthly/bi-monthly mill condition reports. These reports will categorize the components that will need to be replaced/fixed, giving priority to those that are closer to fail and are critical. With this information maintenance task can be efficiently planned preserving the effective operation of the rolling mill. A summary page of a sample report is shown below.

	Machine Name	Condition	1	2	3	4	Points	Page
1	Stand #1	Misalignment	✓				8	1
2	Stand #2	OK					8	1
3	Stand #3	Looseness		✓			7	1
4	Stand #4	Looseness		✓			7	1
5	Stand #5	OK					7	1
6	Stand #6	Impacting		✓			7	1
7	Stand #7	OK					7	1
8	Stand #8	Misalignment	✓				7	2
9	Stand #9	Misalignment		✓			5	2
10	Stand #10	Coupling inspection	✓				5	2
11	Stand #11	Motor bearing			✓		5	2
12	Stand #12	OK					5	2
13	Stand #13	OK					5	2
14	Stand #14	OK					5	3
15	Stand 17 – 1- No-Twist Finish Mill	OK					1	3
16	Stand 18 – 1- No-Twist Finish Mill	OK					1	3
17	Stand 19 – 1- No-Twist Finish Mill	OK					1	3
18	Stand 20 1- No-Twist Finish Mill	OK					1	3
19	Stand 21 – 1- No-Twist Finish Mill	OK					1	3
20	Stand 22 – 1- No-Twist Finish Mill	OK					1	3
21	Stand 23 – 1- No-Twist Finish Mill	OK					1	3
22	Stand 24 – 1- No-Twist Finish Mill	Driven bevel vibration	✓				1	3
23	Stand 25 – 1- No-Twist Finish Mill	OK					1	3
24	Stand 26 – 1- No-Twist Finish Mill	OK					1	4
25	1 Line NTM 2-HI Speed Increase and	Bearing damage	✓				5	4
26	1 Line NTM 3-HI Gearbox	OK					3	4

Figure 6. Sample Summary Vibration **Report**

Case Analysis: I. Laying Head Maintenance

The Laying Head is a critical peace of equipment that requires special maintenance for long and reliable operation. Some of the basic requirements are:

- Monitor 1x vibration (unbalance) along with overall vibration, balance is required every 6 months.
- Periodically remove scale buildup.
- Maintain position of clamps.
- Maintain weight tolerance of clamps and components.
- Ensure uniform pipe.

Vibration monitoring, besides detecting potential problems in the Laying Head's motor and gearbox, it points if balancing is required before the recommended intervals.
Figure 7 illustrates the high importance of Laying Head balancing, if periodical balance is not performed and operating mill speed is over 50 m/s, the vibration level

escalates exponentially. In this situation unbalance acts as the trigger for Looseness and Resonance, vibrations associated with unbalance will generate damage in bearings and components of the drive.

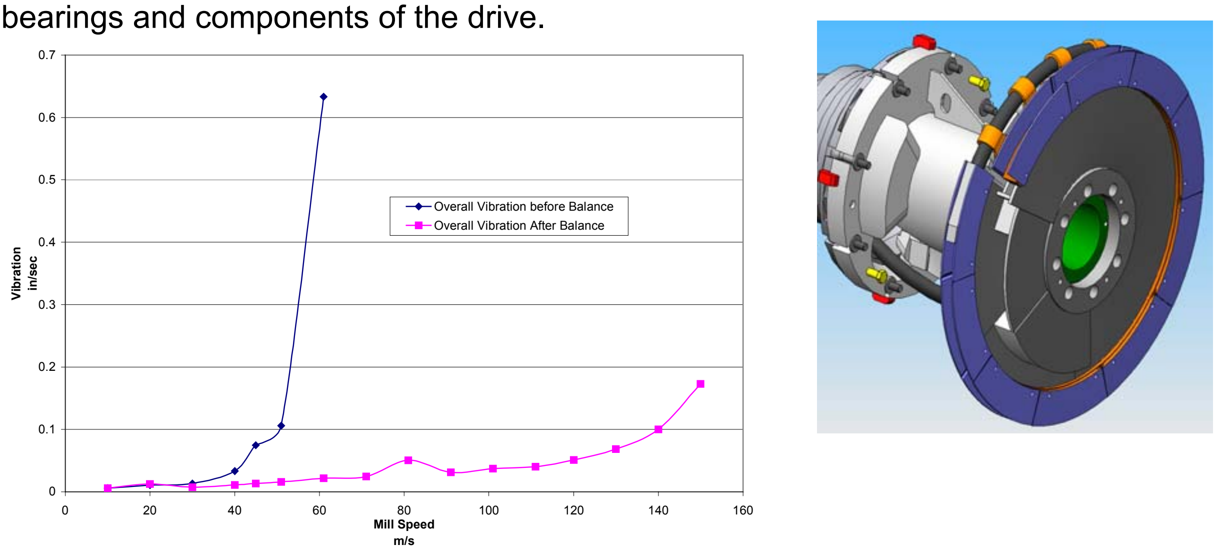

Figure 7. Typical Overall Vibration vs Mill Speed After Laying Head Balance

Newer generations of Laying Heads with Double Bearing design addresses issue of higher harmonic vibration, due to an added external force that restrains looseness. This is significant improvement increases reliability; however, it still requires periodic balancing and normal maintenance.

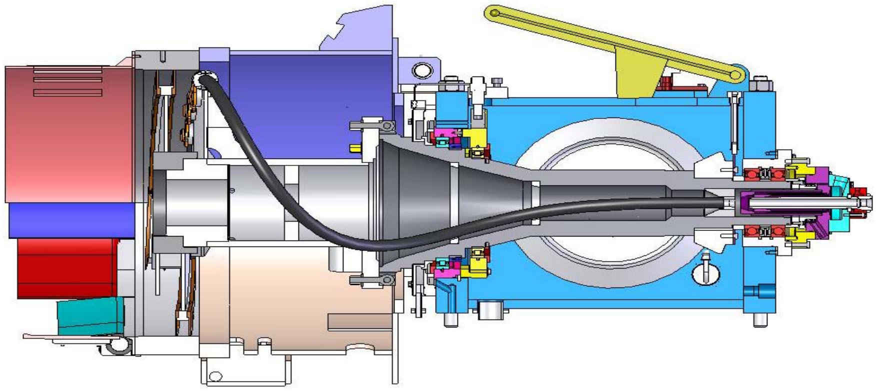

Figure 8. Laying Head with Double Bearing Design

Case Analysis: II. NTM Stand Bearing Failure

This is an illustrative example of bearing failure detection at the nucleation stage and correction, the vibration data was taken from a NTM in a Rolling Mill in North America. One of the findings of the report was matching frequencies with the line shaft thrust bearing (162250E) inner race defect.

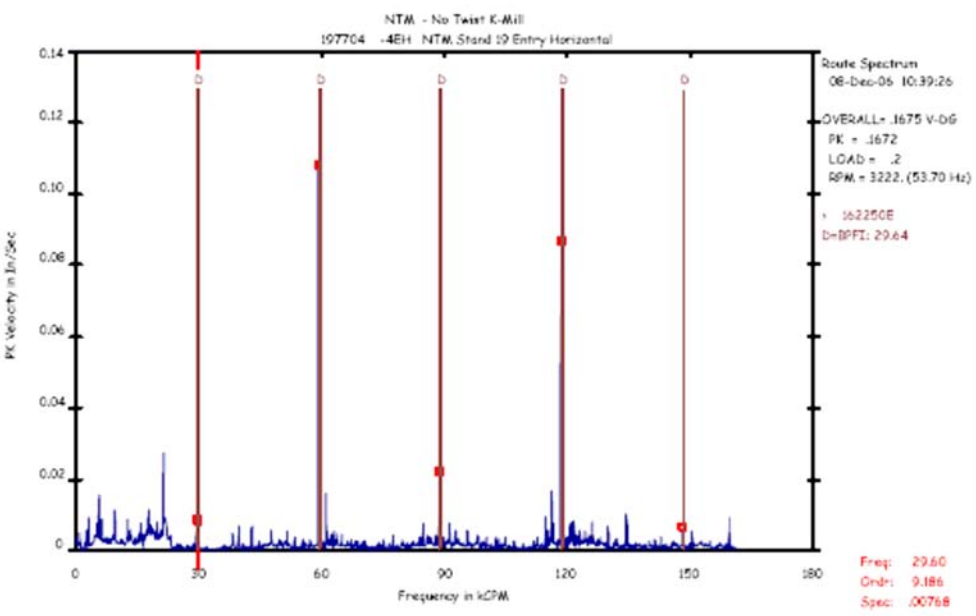

Figure 9. NTM Line Shaft Bearing Failure

During rebuild at Morgan, the inner race of the line shaft thrust bearing (162250E) was found to have four areas of pitting located in the ball track and spaced equal to the ball pitch spacing of the bearing.

The indications appear to be pitting which was initiated by corrosion. These conditions suggest that the mill sat idle for some period of time with water present in the oil. The contact area between the four balls at the bottom of the bearing and the inner race began to pit due to corrosion. Continued operation results in propagation of the pitted areas.

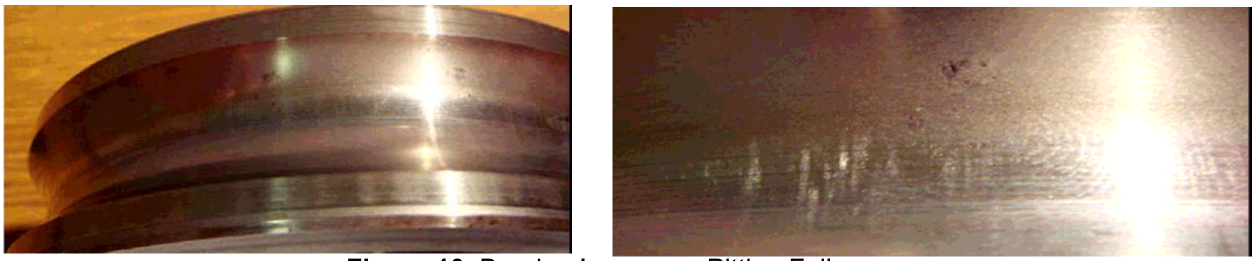

Figure 10. Bearing Inner race Pitting Failure

It is apparent from the close up photo of a single pitted area that a larger piece is ready to break out. At some time, depending on mill operating conditions, these areas would progress to deep spalling and cause bearing failure.

The significant fact is that in a confirmed case of corrosion pitting, like this one, there is likely to be other bearing locations that are on the same lubricating system that will follow the same path to failure.

Oil Analysis

The lubrication system's function is to provide a reliable source of oil to the load-carrying element of the drive train, bearings and gears, at a specified quantity, temperature, and cleanliness.

Periodic oil cleanliness monitoring is always recommended to protect the mechanical equipment and avoid premature failures. Periodic testing prolongs lubricant life and

identifies wear metals that may indicate early stages of primary drive component failure.
Excess water and contamination degrade the oil's ability to maintain film strength/thickness, leading to failure of critical equipment. It also depletes oil additives and creates an environment inside the lube system that is prone to bacterial and fungus growth. The main source of water ingress is due to roll contact cooling water passing the roll neck seals. Other parameters to consider, besides oil cleanliness, are viscosity, total acid number, additive levels and Wear Metals.
Morgan can provide Lubrication System and Mechanical Audits to prevent water ingress and insure these criteria are met consistently.
Morgan also offers an integrated online monitoring system for oil humidity and temperature called Lowtas. This system measures humidity expressed as a percentage of saturation point, also known as % relative humidity - %RH. Water Sensors are placed at key positions along the piping system being communicated to the host pc though a RS485 Serial Link.
The Lowtas Graphical Operator interface displays and records individual readings from each sensor.The data can be displayed in both real-time and historical formats. Each reading is accessed against established warning and alarm limits.
Lowtas online system is also used in other applications such as lubricating oils, hydraulic fluids, fire resistant and fluids fuel oils.

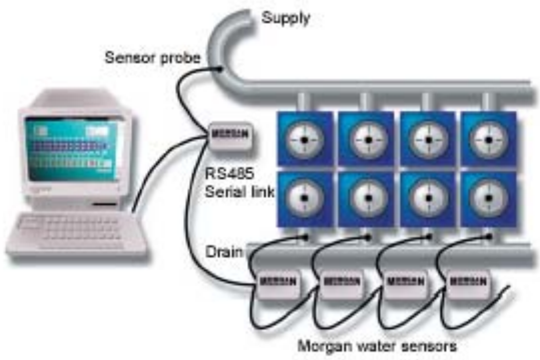

Figure 11. Lowtas Oil Humidity and Temperature Monitoring System

The main benefits of Lowtas are as follows:

- Reduce Costly unscheduled downtime.
- Improve determination of planned maintenance
- Extends equipment life
- Enables identification of ingress location
- Unlimited expansion capabilities
- Simple to use and install
- Accuracy +/- % per sensor (%RH)
- Alarming and Trending
- Integration capabilities with other fluid conditioning systems
- Sensor enable/disable facility
- Applicable to many fluid systems

Thermography

This service identifies and measures variations in the heat emitted by electrical and/or mechanical components where direct temperature measurements would be impractical or unsafe. Using a Radiometer, a thermal image is created, highlighting temperature gradients and values. Subtle or extreme changes in temperature can indicate an anomaly, possibly resulting in an unsafe or inefficient operating condition. Because it detects potential problems anytime energy is reflected, absorbed, or emitted (the parameter measured is energy), it is applicable to a wide variety of machines and systems. Thermography is ideal for determining electrical problems, some of which are undetectable by other PDM methods. However these techniques support the findings of other PDM methods for more severe mechanical problems. Besides, it allows data collector to acquire information regarding dangerous equipment from safe distances.

Morgan's Peace of Mind® Program

The goal of Morgan Construction Company's "Peace of Mind®" maintenance program is to maximize mill utilization by maintaining optimal running conditions on critical mill equipment with special focus on Pre-Finishing Mills, No-Twist® Mills, Reducing/Sizing Mills, Pinch Rolls and Laying Heads.

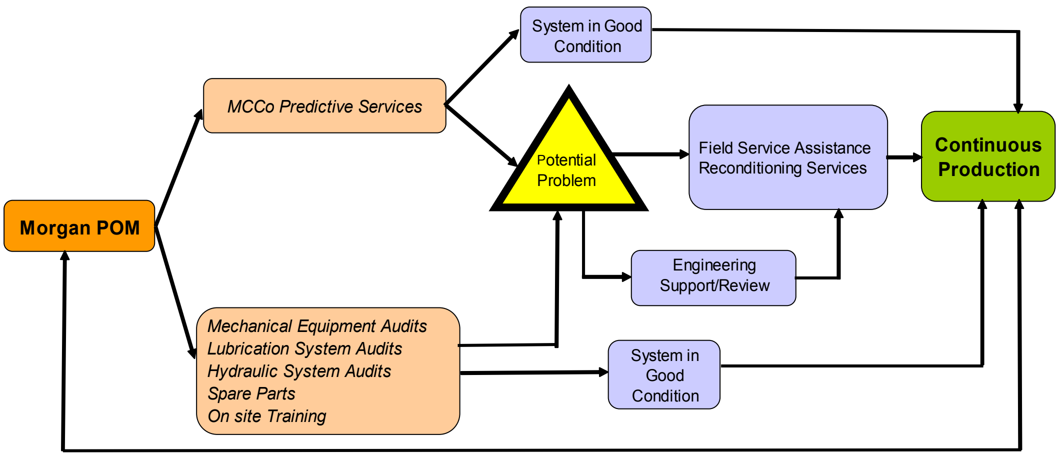

Figure 12. The Morgan Peace of Mind Program (POM)

Predictive services can be integrated with mechanical equipment audits, as well as oil and hydraulics system assessments. Engineering/technical support, on site training and fast delivery of spare parts are available. All these services together constitute the Morgan's Peace of Mind Program (POM). The chart above illustrates the capabilities of the POM maintenance techniques to optimize mill utilization.

Why Morgan Predictive Services?

Morgan Construction Company 115 plus-year history of steel mills design and servicing expertise has lead to the production of the finest and most robust rolling mills in the world. This reality is fully reflected in our unsurpassed knowledge and expertise in Steel Mills. Morgan's absolute knowledge of equipment design, installation, operation, spares, rebuilds and upgrades provides optimum Predictive Maintenance Techniques.
For years Morgan has used its highly skilled predictive resources to test, develop and commission its high tech equipment. Predictive services are required to assure the best possible chance of maximizing equipment availability. Every manufacturing

process deserves the best opportunity to guarantee its performance. The extreme pressures associated with minimizing downtime, meeting strict delivery performance (JIT) and cost reductions can be best served with Morgan's high tech approach to predictive services. Morgan's expanded service opens the door to its years of leadership with rotating equipment, while closing the loop between your process, our design engineering capabilities, field services, scheduling and spares.

Morgan Construction's experienced engineering and technical staff (Mechanical, Electrical, Fluids, Process Control, Metallurgical, Manufacturing and Rolling Engineering) is in full interaction with Predictive services to obtain the best results under continuous improvements. Our extensive knowledge of Maintenance programs allow us to always provide complete solution for any type of machinery and maintenance problems.

Morgan Predictive services is committed to provide the most advanced technologies, with complex sensor application and advanced signal processing, also making sure that our technology is simple to use and affordable, even offering no cost leases for vibration data collectors.

Morgan Construction success fully relies in our customer's accomplishments in the steel industry. Morgan Predictive Services enhances mill productivity of our customers' facilities Making Morgan the perfect solution to optimize your mill maintenance program.