

Optimizing Mill Circuit Pump Reliability: A Comprehensive Approach for Pump Selection, Design, and Continuous Improvement

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INTRODUCTION

Mill circuit pumps are vital for the operation of the mill plant and are often referred to as the *heart* of the mill circuit. Without these pumps, nothing moves within the mill circuit as shown in Figure 1A. Centrifugal pumps have become the industry standard for this demanding application. Erosive wear, caused by the size and type of particles, typically encountered during pumping operations, poses a significant challenge. Mill circuit pump failures can cause substantial financial losses. To mitigate this problem, manufacturers have developed robust centrifugal slurry pumps to withstand this harsh environment. These pumps are engineered to handle abrasive materials and provide reliable performance. An unscheduled stoppage due to pump failure can be extremely costly, outweighing the expense of individual components or even the entire pump unit. An example of a typical mill circuit pump Total Cost of Ownership (TCO) is illustrated in Figure 1B. It is essential that the complete pump give reliable and predictable wear life within the set milling cycles of the plant.

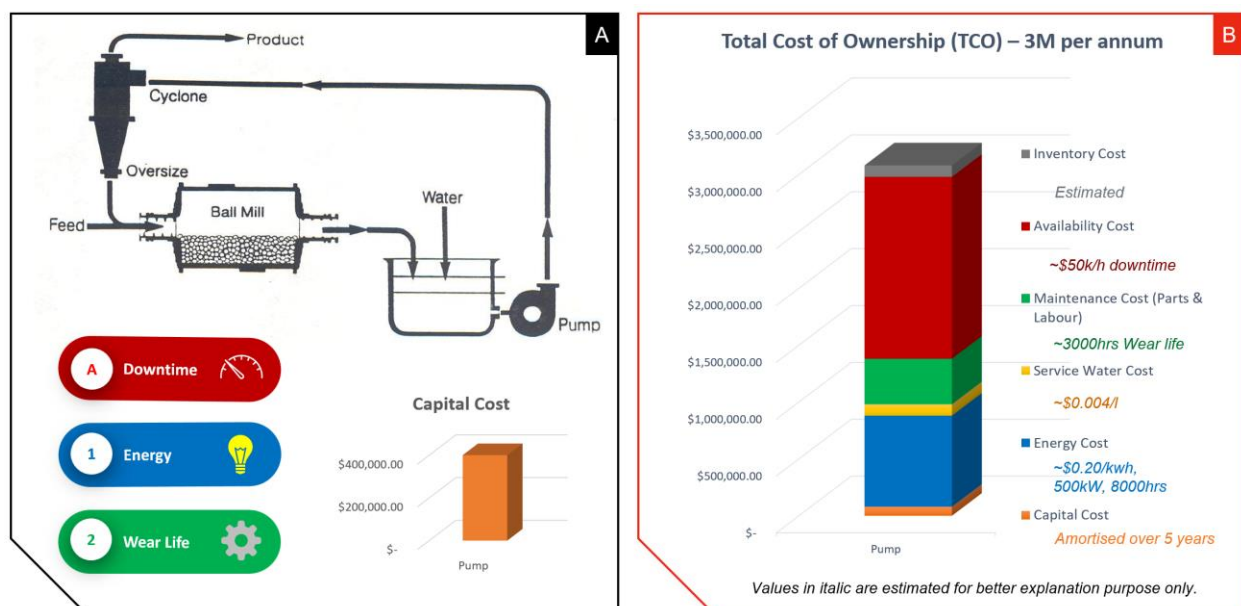


Figure 1: (a) Mill Circuit pump with key important factors and (b) Total Cost of Ownership of a typical mill pump

This paper explains the design principles of mill circuit pumps, detailing the selection methodology including preferred operating range, slurry class and appropriate materials for the wet end. It also delves into continuous improvement strategies such as condition monitoring and savings potentials by proper considerations. These improvement strategies include data-driven monitoring, prescriptive maintenance, and root cause analysis, all aimed at mitigating erosive wear and maximise pump life. Furthermore, practical recommendations, case studies, and insights into the role of digitalization are provided to enhance pump reliability.

MILL CIRCUIT PUMP CONSIDERATIONS

The mill circuit pump considerations range from design, selection, operation and maintenance.

Design of Mill Circuit Pumps

The design of mill circuit pumps plays a pivotal role due to the extreme wear they endure during their operational life. When evaluating pump design, several critical factors must be taken into account. These include sustained output, efficiency throughout its wear life, safe and ease of maintenance, hydraulic profile at inlet, all contribute to ensure a synchronised uptime with the mill allowing for planned maintenance of the full circuit at once. Various factors such as modular structure, the inlet velocity consideration and reducing inventory complexity are discussed in detail. Additionally, durability is key to handle severely abrasive slurries.

Selection of the right Mill Circuit Pumps

The range of solids being pumped, their concentration, the solids specific gravity, hardness and shape can vary dramatically. In fact, the Hydraulic Institute (2016) classifies slurry into 4 classes, ranging from 'Light' (Class 1) to 'Very Heavy' (Class 4). The impact of this various slurry classes on the wear of the wetted components of the pump ranges from pumps lasting potentially 18 months in the Light application to as low as a few weeks in the Very Heavy application. Furthermore, the Hydraulic Institute (2016) guides selection of pumps based on Preferred Operating Range (POR) to match the slurry classes. The mill circuit application typically fall as a class 3 or class 4 where careful selection of pumps must be followed understanding the nature of slurry. For a class 4 service, the pump is generally recommended to be selected between 60% and 100% of its Best Efficiency Point (BEP). Operating towards the left of the BEP, as illustrated in Figure 2, can lead to particle laden fluid sitting and spinning within the pump, causing turbulence and accelerated wear. Therefore, maintaining a tighter bandwidth is essential for prolonged pump life and efficient mill circuit operation.

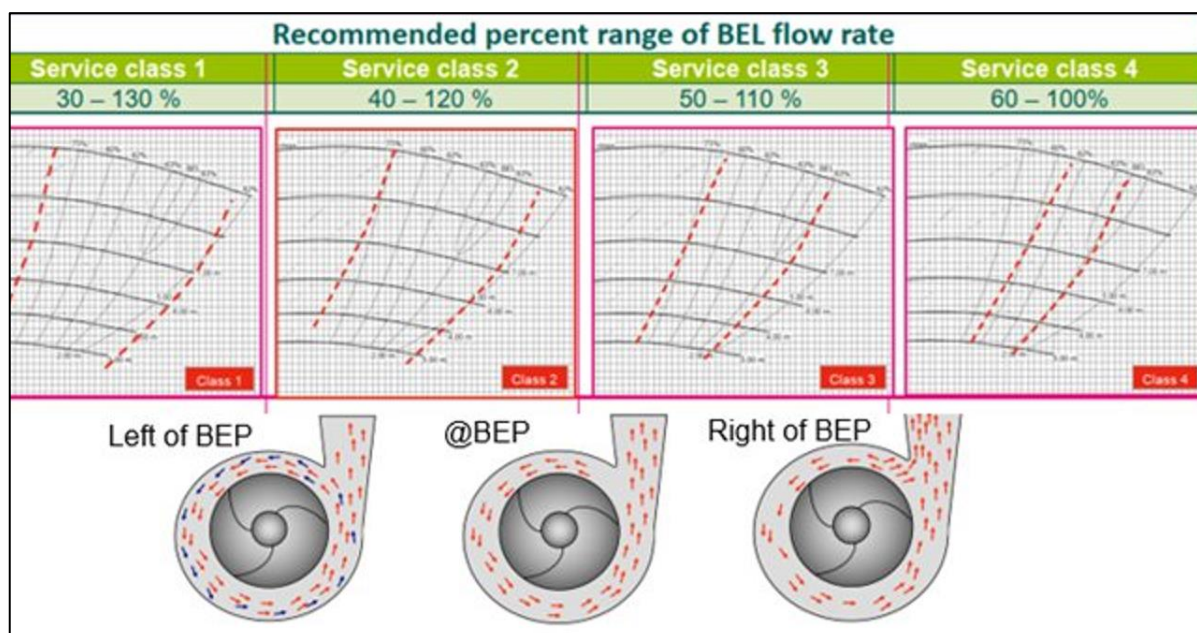


Figure 2: Recommended operating range of BEL flow rate per service class

Maintenance & Operations

Mill discharge pumps require swift and efficient maintenance due to predetermined milling cycles and brief shutdown windows. Modern pumps often allow for adjustable impeller clearances to optimize performance throughout their lifespan. Key practices for maximising uptime include clearance adjustment to maintain optimal spacing between the impeller and inlet liner for maximum efficiency and wear reduction. Follow manufacture's torque recommendations for all mechanical components during commissioning is essential. Additionally, use of quick serviceability designs such as complete wet-ends removals or slide-base streamlines maintenance.

The operation of a mill discharge pump is intricately linked with maintenance practices, both crucial for optimal performance. As processing plants evolve, changes in duty points are inevitable, driven by fluctuations in market demand. While some equipment may not be significantly affected by increased flow, pumps can experience a shift from their most efficient operating point to a critical range. Factors such as alterations in feed material and pipework installations can worsen issues, leading to higher friction losses within the system. Even minor adjustments in flow or head can significantly impact the pump's wear life, potentially causing recirculation or inlet velocity issues. While speed adjustments can sometimes mitigate these challenges, in other cases, changing the pump size may be necessary to better align with the altered application. Failing to account for these changes can transform a previously reliable pump into a maintenance burden.

CONTINUOUS IMPROVEMENT STRATEGIES

The strategy includes pumps condition monitoring services pioneered with digital technologies and savings potentials examples by proper considerations.

Pumps Condition Monitoring Service

The implementation of digitalisation offers the advantage of predictive maintenance. It is crucial to assess whether existing mill discharge pumps can be integrated into a digital system and the benefits this integration can provide. Condition monitoring on pumps is an ideal starting point, which enables the early detection of potential equipment issues before they escalate into failures. This proactive approach is a considerable step forward from the reactive and preventive maintenance practices commonly employed today.

For condition monitoring of rotating equipment, vibration and temperature analysis remains a highly effective and widely used technique. According to Truempi and Yarmoluk (2020), 67% of rotating equipment failures stem from lubrication or bearing issues often triggered by shaft vibration. Similarly, seal failures tops the list for pumps often caused by shaft deflection or vibration as well. Common causes include;

- Design – over/undersized pump (running away from best efficiency point), process variations, variable speed drives.
- Installation issues – Pipe strain, misalignment, resonance, thermal growth and poor foundation
- Operational problems – deadheading, starving, incorrect header operation, plugged strainers/filters, overpressure, debris in line.
- Lubrication – washout, contamination, lack of proper lubrication
- Wear challenges – bearing, impeller, case clearances.

The advent of wireless sensors has revolutionized data collection, significantly reducing the time required for gathering information. Unlike labor-intensive manual methods that could take weeks, wireless sensors enable data streams within minutes. This enhanced efficiency in data collection allows experts to concentrate on assets that require immediate attention. An example of installation in a mill circuit application is presented in Figure 3A. The system emphasizes ease of installation and operation, operating independently without the need for integration with customer PLCs, thus mitigating common implementation challenges found in existing solutions. The gateway ensures reliable data transmission through either a 4G cellular connection or Ethernet. The general architecture is outlined in Figure 3B, while common fault types are detailed in Table 1.

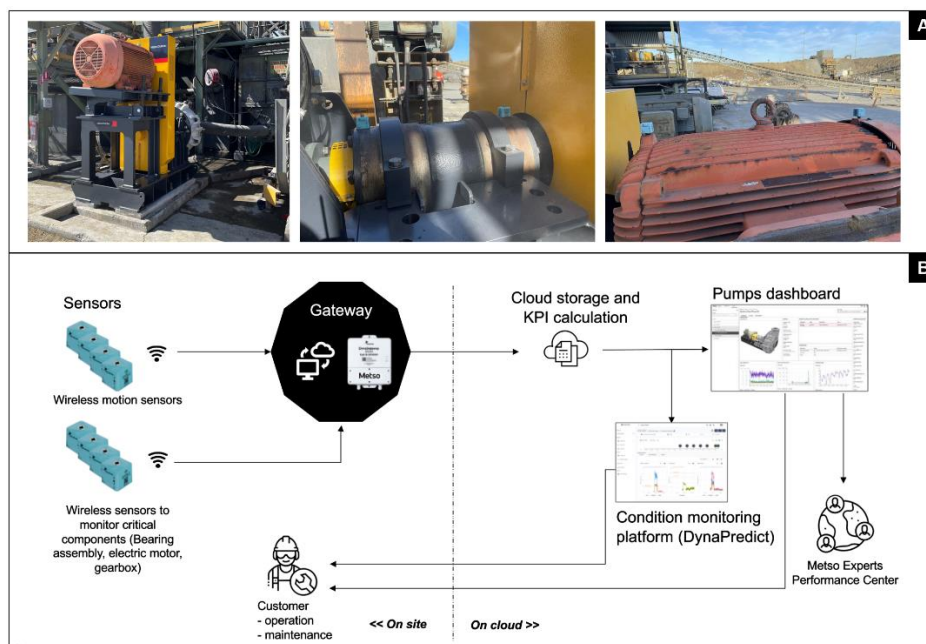


Figure 3: (a) Example of installation on site and (b) general architecture of the system

Savings potentials by proper considerations

The Total Cost of Ownership (TCO) analysis serves as a valuable tool for comprehending the continuous improvement of mill circuit pump costs. While the specifics of TCO can vary significantly from case to case, it generally encompasses several key components:

1. **Capital Costs:** represent the initial investment required to purchase the equipment.
2. **Energy Costs:** once the pump is installed and operational, the power consumed comes at a cost.
3. **Maintenance Costs:** include both spare parts and labour needed to maintain the pump.
4. **Inventory Costs:** encompass the expenses incurred to maintain readily available spare parts, often due to remote locations or frequent changeouts.
5. **Availability Costs:** the pump is the heart of the mill circuit. Downtime directly impacts production, especially for duty-only pumps. The financial loss per hour during downtime can be substantial.
6. **Service Water Costs:** includes use of fresh seal water, essential for gland sealing, adds to operational expenses.

By following appropriate considerations and pursuing continuous improvement, TCO can be significantly reduced, leading to more efficient operations and cost savings. See Figure 4 for further details.

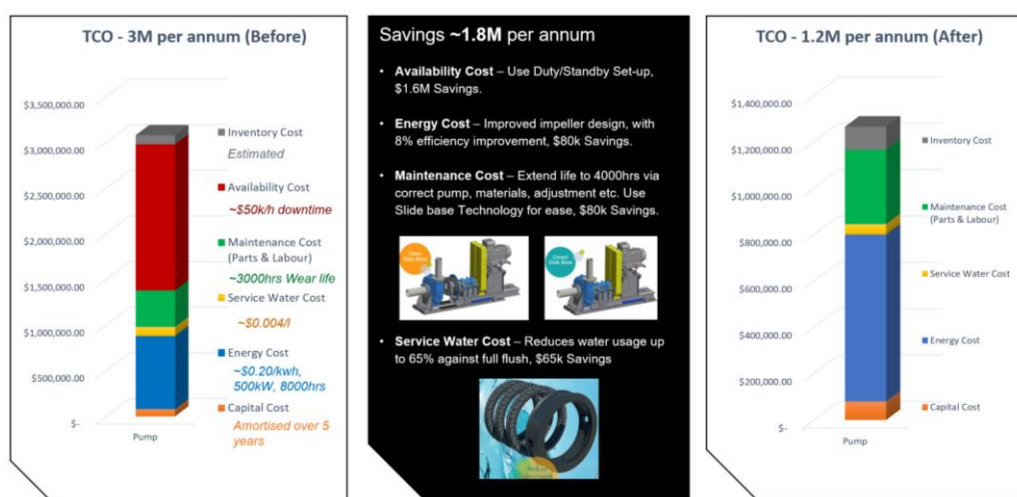
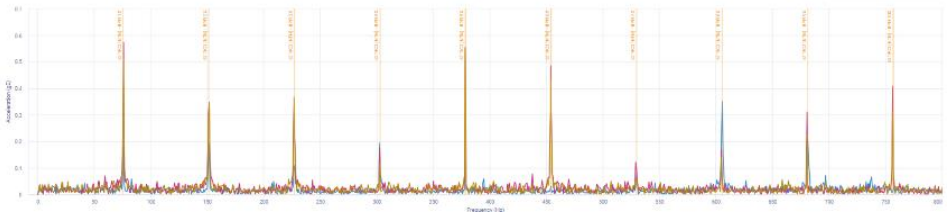
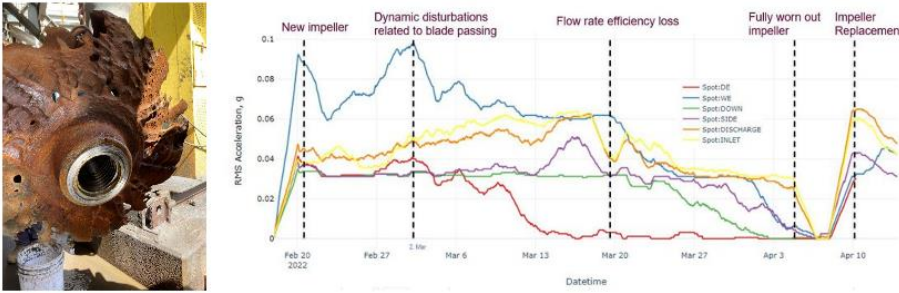


Figure 4: TCO reduction using appropriate selection, design and application considerations

Table 1: Common fault types identified

Fault type	Description
Bearing Wear	Vibration analysis is well known to detect bearing wear. In multiple installations, the authors have found cases of bearing wear both in pump and motor. One case was when the customer used an existing motor from site during an upgrade of pump size. Our remote monitoring experts detected rising vibration levels, specifically related to the Ball Pass Frequency of the inner race (BPFI) shape on the motor bearing. 
Lubrication	Multiple intervention of excess lubrication or lack of lubrication has been identified using condition monitoring services. In the case below excessive grease was applied by the customer on the pump by which the temperature reading went above 70°C above alarm level configured. 
Impeller Wear	Impeller is a critical component that limits the life of the pump. During diagnosis of a case, the authors explored an interesting way to identify wear on the five-vane impeller using blade pass frequency. 

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