Big Data Management and the Application of Reliability Engineering for the Optimization of Critical Components

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Abstract

Hydro Bauxite & Alumina operates two pump station dedicated to the transportation of slurry that feeds the Alunorte refinery. This system utilizes positive displacement triplex diaphragm pumps, powered by 2 000 hp motors, and play a critical role in ore transportation. Given the strategic importance of the positive displacement pumps for process continuity and the significant amount of equipment in operation, rigorous monitoring of the service life of critical components is essential. The integration of Big Data management and reliability engineering applications enable the acquisition of accurate and reliable data, supporting the development of optimal maintenance strategies. Such monitoring ensures operational reliability by enabling the timely replacement of components as they reach the end of their service life. Furthermore, it aims to optimize replacement planning, thereby avoiding overlapping maintenance activities that could lead to workload peaks and increased operational costs. To achieve these objectives, a monitoring system based on the concept of Residual Life was implemented. This approach evaluates the remaining service life of each critical component, providing a clear metric to optimize the maintenance interval. As a result, operational continuity is ensured with greater efficiency and predictability, reinforcing process reliability, and optimizing resource utilization.

Keywords: Big Data, Reliability Engineering, Critical Component.

1. Introduction

Hydro Bauxite & Alumina, a key component in Hydro's global strategy, began operations in March 2007. Since then, the mine, located on the Miltônia 3 Plateau in northeastern Pará, has handled around 16 million tonnes of ore per year, 11 million of which is bauxite. After extraction, the ore undergoes a rigorous beneficiation process—including crushing, grinding, and classification. The processing is carried out using a wet method, and in the end, the bauxite, in slurry form, is ready for transport.

The beneficiated bauxite is pumped through a 244 km slurry pipeline—the first in the world to transport this type of ore—on a route connecting the Paragominas Mine to the Alunorte refinery in Barcarena, where the bauxite is transformed into alumina, an essential raw material for aluminium production. This pioneering solution eliminates heavy vehicle traffic, resulting in lower CO_2 emissions and a safer, more efficient transport system, reinforcing our commitment to sustainability and innovation in the aluminium industry.

Along its route, the pipeline crosses seven municipalities and four major rivers. The system operates at a maximum pressure of 90 bars, with two pumping stations: one at Paragominas Mining (MPSA) in Paragominas, equipped with seven pumps, and another in Tomé-Açu, equipped with six pumps. With a flow rate between 1 800 and 1 950 m^3/h, these stations ensure a continuous and safe flow of the slurry. The bauxite is transported using triple positive displacement pumps, model TZPM 2000 – single-acting piston and diaphragm pumps with three cylinders, driven by a crankshaft and designed to operate with mineral slurries under high pressure.

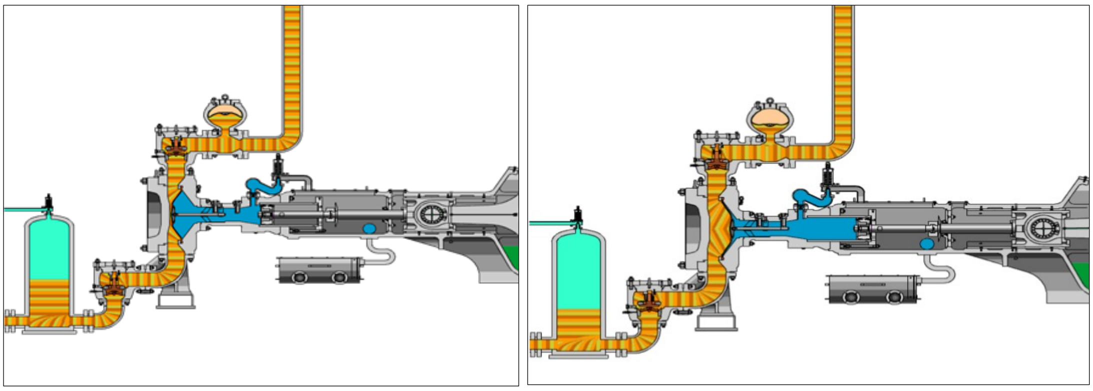

Figure 1. Representation of the Diaphragm Filling and Emptying.

The piston fits into the cylinder rod, which operates inside a lined cylinder – both of which are highly resistant to wear. In the event that solids penetrate the drive fluid compartment due to a diaphragm rupture, no immediate damage will occur [1].

The piston has two sets of seals, as shown in Figure 2: one that seals the pressure side (020) and another that prevents the suction of air and oil (21). Between the two sets of seals, a ring (012) is placed to support the gravitational load of the piston and the piston rod [1].

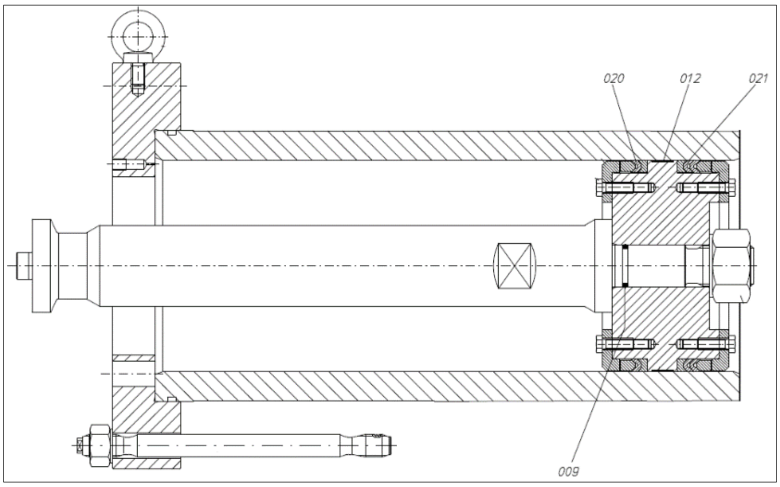

Figure 2. Piston seal rings in the Piston Unit.

The manufacturer's manual states that both the diaphragms and the piston seal sets have a service life of 8 000 hours, and their replacement is recommended after this period [1].

A diaphragm can fail due to excessive pressure in the drive fluid, excessive hammering caused by high pulsations, lack of drive fluid, contaminants in the slurry, or fatigue. Any of these possible causes can allow slurry to pass into the drive fluid section, leading to abrasive wear of the components and consequently greater damage to the pump's operation [1].

The piston seals, in turn, may fail due to severe localized wear around the circumference, grooves on the sealing rings, a rough texture on the rings' surface, and wear on the outer diameter.

5. Conclusion

Based on the reliability analysis conducted, with data collected over the years, the component's lifespan, which was previously 8 000 hours, has exceeded the expected life by three times without compromising the operational performance of the pump.
The quality and reliability of a structured database are essential for defining operational limits and for the development of effective decision-making strategies, directly impacting the reduction of operational costs and increasing asset availability.

Among the various monitored elements, some critical components – as defined by the manufacturers – have a predefined lifespan, requiring periodic replacement to ensure continuous operation and system reliability. To address this, a critical component lifespan control dashboard was implemented, allowing the technical team to monitor the lifecycle of these items in real-time. Thus, whenever the system indicates that a particular component has reached its operational limit, the replacement is promptly scheduled and executed, preventing unexpected failures and optimizing predictive maintenance.

With the change in the data collection method, it is possible to identify a gain in the lifespan of the components, considering that preventive and corrective pump stops occur over time.

6. References

1. Operation manual of the positive displacement pump GEHO TZPM 2000, Weir Group. https://www.global.weir/pt-BR/brands/geho-positive-displacement-pumps/
2. Wulan et al., (2024), Impact of ERP System Implementation on Operational and Financial Efficiency in Manufacturing Industry, *Journal of Economic Education and Entrepreneurship Studies*, 5 (3), 491-501.
3. F. Ghaiti and M. Laghrissi, Implementation of the management system maintenance in SAP, *Proceedings of 2013 International Conference on Industrial Engineering and Systems Management (IESM)*, Agdal, Morocco, 2013, 1-6.
4. B. Balamurugan et al., (2022), *Big Data Analytics for Smart Manufacturing*, CRC Press.
5. D. Thomas and B. Weiss, (2021), Maintenance Costs and Advanced Maintenance Techniques: Survey and Analysis, *International Journal of Prognostics and Health Management,* Vol. 12 No. 1 (2021).
6. John D. Campbell and Andrew K.S. Jardine, *Maintenance Excellence: Optimizing Equipment Life-Cycle Decisions*, CRC Press, 2001.
7. H. Dan et al., Economic optimal model integrating statistical process control and preventive maintenance, *IEEE International Conference of Online Analysis and Computing Science (ICOACS),* Chongqing, China, 2016, 218-224, DOI: 10.1109/ICOACS.2016.7563083.
8. A. Birolini, *Reliability Engineering: Theory and Practice*, Springer, 2017.
9. J. Pulido, Life data analysis using the competing failure modes technique, *Annual Reliability and Maintainability Symposium (RAMS),* Palm Harbor, FL, USA, 2015, 1-6, DOI: 10.1109/RAMS.2015.7105142.
10. M. Xu and H. Mao, q-Weibull Distributions: Perspectives and Applications in Reliability Engineering, *IEEE Transactions on Reliability,* (2024): 1-14, DOI: 10.1109/TR.2024.344828.
11. William Q. Meeker and Luis A. Escobar, *Statistical Methods for Reliability Data*, Wiley, 2014, 712 pages.