Scholars Journal of Engineering and Technology

OPEN ACCESS

Abbreviated Key Title: Sch J Eng Tech
ISSN 2347-9523 (Print) | ISSN 2321-435X (Online)
Journal homepage: https://saspublishers.com

Evaluation of Centrifugal Pump Availability Trends and Analysis

Ahiamadu Jonathan Okirie[1*]

[1]Department of Mechanical Engineering, University of Port Harcourt, Nigeria

DOI: 10.36347/sjet.2024.v12i04.003 | **Received:** 13.03.2024 | **Accepted:** 19.04.2024 | **Published:** 26.04.2024

***Corresponding author:** Ahiamadu Jonathan Okirie
Department of Mechanical Engineering, University of Port Harcourt, Nigeria

Abstract | **Original Research Article**

Centrifugal pumps are essential elements in industrial systems, facilitating fluid transfer and pressure generation across various applications. This study explores the vital task of evaluating centrifugal pump availability trends, focusing on three United Pumps crude delivery centrifugal pumps (P-90A, P-90B, and P-90C) over a span of seven years (2009-2015). With the use of derived equations and annual run-hours data from the facility's operations and maintenance database, the study ascertained the availability of the pumps. The findings and analysis showed that pumps P-90A and P-90B had significant decline in availability over the evaluation period (2009-2015), with P-90A finally failing in 2014. P-90C on the other hand, demonstrated relatively higher availability levels even though it was trending downward. The main cause of the decline in availability is attributed to the Original Equipment Manufacturers' decision to discontinue production of the pump model and its spares, which led to the substitution of locally made components for OEM parts. The study highlights the critical role, OEM support and its genuine spare parts play in optimising pump availability, reliability, and continuous operation—all of which prolong the pump's operating lifespan. It suggests improved methods, regular inspections, preventive maintenance, re-evaluating the quality of spare parts, and investigating replacement options. The study provides recommendations for improving pumping station performance and efficiency, based on empirical data and analysis, to industry stakeholders involved in crude oil delivery operations.

Keywords: Availability trend, Centrifugal pump, Pump availability, Performance analysis, Spare parts, Original Equipment Manufacturer.

INTRODUCTION

Centrifugal pumps are essential components of fluid handling systems across various industries, such as water supply, oil and gas production, wastewater treatment, chemical processing, and petroleum refining. They are used to transfer liquids from low-pressure to high pressure in a system, the liquid would move in the opposite direction because of the pressure difference [1], their existence is practically in all plant processes, they are essential for assessing plant robustness and promoting liquid movement [2]. Durability of centrifugal pump components is important for increased centrifugal pump availability, their reliability and availability performance guarantees continuous output, upholds process effectiveness, and reduces downtime, according to [3], cast iron and steel are used in the production of centrifugal pump parts, which can be melted into new products, cast iron parts can be reused, reducing environmental waste and costs. The natural environment can cause metal structures to corrode, so it's important to use non-ferrous metals and alloys instead. Since it presents significant challenges to achieving and maintaining high levels of pump availability due to scenarios associated with ageing infrastructure, poor maintenance practices, and unplanned failures, experts in the industry recommend the API-610 pump standard for reliable and high-performance pumps [4, 5]. Research indicates that eliminating the primary cause of failure can significantly enhance both the availability and availability of the pump system.

Centrifugal pump maintenance can be facilitated by monthly or annual reports that prioritise units according to availability or criticality [6], when a system's failure rates are low, overall optimal system availability can be attained [7]. Availability studies uses a multidisciplinary approach that includes engineering principles, data collection and analysis techniques, and industry insights to provide practical suggestions for improving the availability of centrifugal pumps. According to a study conducted by [8], centrifugal pump failures can be caused by excessive stress, component strength reduction, load variation, and poor design; these problems can be predicted using fault tree analysis and an FMEA chart, which can also be used to prioritise

maintenance tasks and ensure smooth operation and machine longevity. Continuous pump operation is essential for plant operation in industries such as paper, textile, and refineries [9]. However, stakeholders can proactively manage pump assets, minimise disruptions, and optimize resource allocation by identifying the root causes of downtime, evaluating the efficacy of maintenance interventions, and forecasting potential failure modes. Improvements in centrifugal pump performance according to [10] can result in notable increase in efficiency and cost savings, this can be achieved by conducting thorough examination of the availability trends of centrifugal pumps and in-depth analysis to identify critical factors influencing their availability and performance. Building databases enables the evaluation of the financial feasibility of proposed investments in companies, buildings, and process units, which is crucial for the development of industrial Reliability, Availability and Maintainability (RAM) programmes [11]. RAM analyses are also necessary for identifying underlying issues, improving equipment and system reliability, and putting effective maintenance strategies into practice.

To improve maintenance strategy, maximize system reliability and availability, and expedite asset management processes, it is imperative to understand pump availability trends [12]. This study examines trends in pump availability, with a particular focus on the decline in three United Pumps S-3×9WMSNM centrifugal pumps' availability at a Bpl oil production facility in the Niger Delta region of Nigeria. This pumps are used to deliver crude oil to a designated location. These units have been operational since 1981, when they were installed and commissioned. The pump model and its replacement parts are no longer being produced by United Pumps, the Original Equipment Manufacturer. To keep the machinery operating, local suppliers produced replacement parts. This research is significant because centrifugal pumps are widely used in a variety of industries, including manufacturing, water treatment, oil and gas, and agriculture. Prior to now, no research had been conducted on this facility's delivery pumps; carrying out this study will provide information about the current condition of the units in question and allow for appropriate measure to be put in place to enhance the pumping station's effectiveness and performance.

METHOLOGY

A statistical analysis of availability is necessary to create strategies for planning, operating, and maintaining systems. Centrifugal pump maintenance can be facilitated by monthly or annual reports that prioritise units according to availability or criticality [13]. To gather essential data, a pump station needs to use the right data collection methods. The facility's operations and maintenance database provided the run-hours of three United Pumps crude delivery centrifugal pumps (P-90A, P-90B, and P-90C) over a seven-year period. The results were displayed in a table. The availability of the units were determined by using derived equations and annual run hours. Analysis was carried out to establish availability trends and the causes of decline in availability. A thorough understanding of the units' availability was provided by the use of line graphs to show these trends.

The percentage of time that a pump is usable is indicated by the availability (A), because of friction and wear on its engineering components, the pump's availability and reliability may decline over time [14]. An operational and well-maintained plant has a high availability rate; on the other hand, a low availability rate indicates problems that need to be fixed. The percentage of a certain period, usually a year that a pump is available and operational is referred to as its availability. Availability is a key performance indicator for evaluating the efficacy of operating and maintenance deployment, it is a measure of a pump's availability and performance. Availability and reliability are two distinct metrics used to assess the performance of a system or piece of equipment. One could think of reliability as a subset of availability. A highly available machine, for instance, might not be reliable. Whereas reliability concerns the effect of lost time, availability concerns the quantity of time lost. The ratio of the pump's entire operating time to the total amount of time it was planned to be available for operation is commonly used to determine its availability, the pump is expected to operate for one year, which amounts to 8760 hours, the formula for its availability calculation is expressed as:

$$A = \frac{\text{Runhours}}{\text{Operating hours}} \times 100 \quad (1)$$

$$A = \frac{\text{Runhours}}{8760} \times 100 \quad (2)$$

This goes to say that the pump can be used to deliver crude for a significant amount of time when it has a high availability, which is desirable. In addition to higher maintenance expenses and potential fines for breaching contracts, low pump availability can also result in lower crude delivery potentials and revenue. During a specific timeframe, like a month or a year, the operating hours of the pump is referred to the total number of hours it was in operation, whereas the downtime hours represent the total number of hours the pump was unavailable for use, because of maintenance, repairs, or other factors.

RESULTS AND DISCUSSIONS

Table 1 shows yearly run hours achieved by the various pumps; P-90A, P-90B and P-90C. Table 2 displays their corresponding availabilities calculated from Equation 2, similarly, Figure 1 shows a line graph displaying trends of availability of the process pumps over the evaluation period (2009-2015).

Table-1: Yearly run-hours of the pumping units

Year	Yearly run-hours (hours)		
	P-90A	P-90B	P-90C
2009	8208	8136	8328
2010	7992	7992	8232
2011	7608	7704	7968
2012	7104	7176	7464
2013	6384	6384	6648
2014	Failed	5256	5280
2015	Failed	3672	3600

Table-2: Availability of various units calculated from Table 1

Year	Units availability (A) (%)		
	P-90A	P-90B	P-90C
2009	94	93	95
2010	91	91	94
2011	87	88	91
2012	81	82	85
2013	73	73	76
2014	Failed	60	62
2015	Failed	42	41

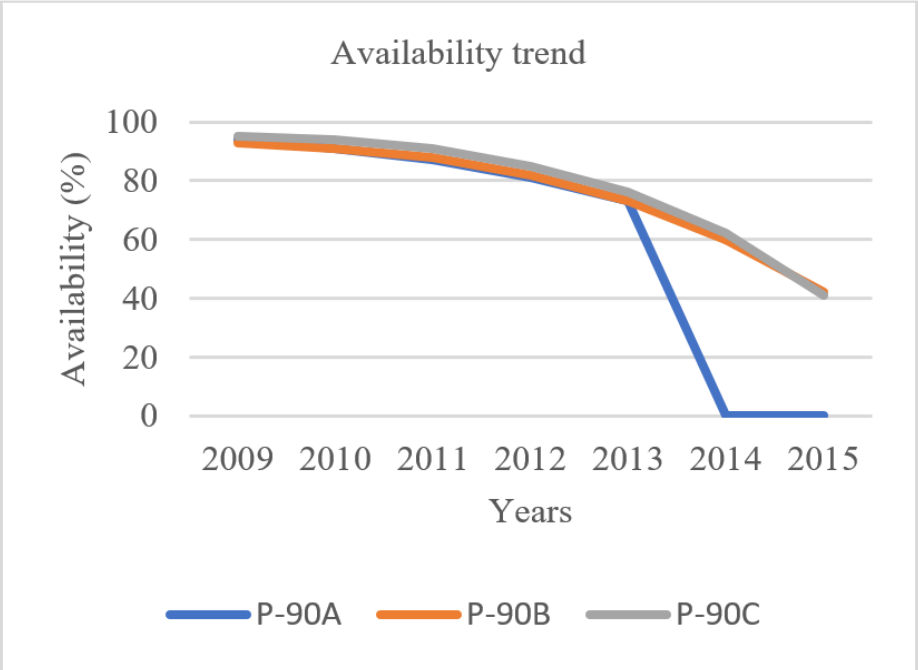

Fig-1: Line chart of availability trend

The availability of the pumps over time is shown in Table 2 as follows. The Pumps P-90A and P-90B were steadily becoming less available. While Pump P-90A experienced a decline from 94% in 2009 to 73% in 2013 and ultimately failed in 2014, continuing into 2015; Pump P-90B experienced a decline from 93% in 2009 to 42% in 2015. Pump P-90C experienced a decline from 95% in 2009 to 41% in 2015, it however maintained a relatively higher availability interval than Pump P-90A and P-90B. Pump P-90A was not available in the years 2013 and 2014, as shown by the graphical depiction of the availability trend in Figure 1, it corresponds to zero in the chart. Furthermore, it was found that, up until 2009, the pumps had maintained availability values of between 99% and 96% until the Original Equipment Manufacturers (OEM) stopped producing spare parts in 2007. This was due to the OEM's discontinuation of production of that specific pump model, which resulted in the replacement of its spares with locally produced components, which in turn caused an increase in breakdowns and shorter operating times for all the pumps. This scenario also caused a decline in the amount of crude delivery, affecting organizations' revenues. These developments

emphasizes how crucial it is to use sturdy, high-quality spare parts to keep equipment reliable and readily available. The availability analysis highlights how OEM support, spare part sourcing, and equipment maintenance affect the overall longevity and performance of the operating pumps.

Locally made replacement parts may have both favourable and unfavourable effects on pump availability. Advantages include a reduced reliance on OEMs, mitigation of stock shortages, shorter maintenance lead times, opportunities for customisation, and consistent supply. Conversely, disadvantages include frequent failures, insufficient or poorly designed spare parts, decreased availability, higher maintenance requirements and potentially voided warranties. Lax quality control and testing procedures can have an effect on the long-term availability and performance, pumps might not work perfectly with mediocre replacement parts, which could lead to more malfunctions and problems with operation. In addition to voiding warranties from the original manufacturer, utilising non-OEM spare parts increases equipment risk and costs. To ensure the functionality and safety of these replacement parts, it is crucial to assess their quality and implement routine maintenance, quality control, and monitoring procedures.

Pump failures can impact system availability and processes, resulting in lower output, delays in production, and financial losses. They may also reduce output, which raises the cost of maintenance. In addition to putting the environment, people, and equipment in risk, pump failures can result in spills, leaks, and hazardous situations. Their impact on interconnected systems may also impact the overall efficiency of a facility. Repeated pump failures are indicative of poor equipment quality, insufficient maintenance practices, or unreliability, all of which can bring a company to disrepute. The complete failure of Pump P-90A in 2014 and the gradual decline in Pump P-90B and P-90C's unavailability have had a substantial impact on overall availability of the pumping units. In order to increase pump availability, it is advised to improve maintenance procedures, carry out regular inspections, make timely repairs, and reassess locally produced spare parts; preventive maintenance programmes can lower the frequency of failures, while a thorough inspection of these components can reveal areas that need improvement. Using best-fit parts to retrofit old pumps can improve availability and performance, training and skill development are necessary for maintenance personnel to recognise issues early and perform effective repairs. Pump availability can be increased and trends can be found with the aid of performance metrics, in the event that pumps continue to malfunction, replacement options can be considered.

CONCLUSIONS

The evaluation of centrifugal pump availability trends and analysis underscores the importance of meticulous data collection, comprehensive analysis, and strategic planning in ensuring the availability and longevity of pumping systems. Through an in-depth examination of the availability trends of three United Pumps crude delivery centrifugal pumps (P-90A, P-90B, and P-90C) over a seven-year period, significant insights have been gleaned regarding the factors influencing pump performance and availability. The study findings reveals a decline in the availability of pumps P-90A and P-90B, with Pump P-90A failing entirely in 2014 and Pump P-90B showing a steady decrease over time while pump P-90C, despite a declining trend, maintained higher operational intervals. The root cause analysis linked the decrease in operating times and rise in breakdowns to local production and usage of subpar components and OEM replacement parts production discontinuation.

The impact of locally produced spare parts on pump availability was further highlighted in the study, along with their benefits and drawbacks. While these parts reduce reliance on OEMs and offer faster maintenance process, they also pose risks like reduced availability, increased maintenance requirements, and potential warranty voiding. Therefore, rigorous quality control and regular maintenance are crucial. Pump failures can cause financial losses, environmental hazards, and reputational damage. To improve pump availability, a multifaceted approach is recommended, including evaluating local spare parts, implementing preventive maintenance programs, training maintenance staff, regular performance monitoring, and retrofitting pumps with modern components or outright replacement options.

REFERENCES

1. Thin, K., Khaing, M., Maung A., & Khin, Y. (2008). Design and performance analysis of centrifugal pump. *World Academy of Science, Engineering and Technology*, *46*.
2. Di Febo, M., & Paganini, P. (2015). Centrifugal pump technology in oil and gas refinement. *World Pumps*, *2015*(11), 36-40.
3. Guner, M., & Ozbayer, M. (2020). Centrifugal pump design materials and specifications.
4. Almasi, A. (2014). Process centrifugal pumps in oil and gas plants. *Oil and Gas European Magazine*, *40*(2), 222-223.
5. Misren, M. M. (2014). Reliability, availability and maintainability analysis for main oil line pump by dominant failure modes.
6. Singh, D., & Suhane, A. (2013). Availability of centrifugal pump on the basis of Weibull Analysis. *International Journal of Science and Research (IJSR) ISSN (Online)*: 2319-7064.
7. Danjuma, M., Yusuf, B., & Yusuf, I. (2022). Reliability, availability, maintainability, and

dependability analysis of cold standby series-parallel system. *Journal of Computational and Cognitive Engineering*, *1*(4).

8. Bhandari, R. (2024). A maintenance report on centrifugal pump.
9. Selvakumar, J., & Natarajan, K. (2015). Failure analysis of centrifugal pumps based on survey. *ARPN Journal of Engineering and Applied Sciences*, *10*, 1960-1965.
10. Muradova, Z. (2024). Improving the performance indicator of centrifugal pumps. *Equipment Technologies and Materials*, *9*(01), 05-14.
11. McFadden, R. H. (1990). Developing a database for a reliability, availability, and maintainability improvement program for an industrial plant or commercial Building. *Industry Applications, IEEE Transactions on*, *26*(4), 735-740.
12. Mokhtar, A. A., Misren, M. M., Muhammad, M., & Hussin, H. (2016). RAM analysis of crude oil transfer pumps using dominant failure mode. *ARPN Journal of Engineering and Applied Sciences*, *11*(22), 13348-13352.
13. Singh, D., & Suhane, A. (2013). Availability of centrifugal pump on the basis of Weibull Analysis. *International Journal of Science and Research (IJSR) ISSN (Online)*: 2319-7064.
14. Chikezie, A., & Nonju, G. T. (2023). Availability Assessment of the Centrifugal Pump of Afam VI Gas Plant using Lognormal Distribution. *World Scientific News*, *185*, 163-174.