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A Comparative Assessment of Boat Faulty Shaft Seal to Eradicate Boat Mishap's in Oporoza Community, Delta State, Nigeria

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Abstract:

The aim of this study is to comparatively assess faulty shaft seal in Boats, in order to eradicate Boat mishaps in Oporoza community. Collating the needed data for risk matrix and shaft seal failure analysis, a real-time experimental data collection has been done on three cases in boat engines, by simulating likely faults such as Case A: impeller fouling, Case B: air cooler blockage, and Case C: Filter fouling, to determine variations in engine parameters with records collected showing Case A: impeller fouling had the lowest impact severity with low risk operation. Records showed Leakages 27.4%, excessive wear 20.8%, installation error 14.2%, corrosion 17.9%, and material degradation 17.95% as the prevalent causes of Boat mishaps in Oporoza community. An analysis of surveyed questionnaires from Boat operators in Oporoza community was carried out and participants provided data. Failure analysis and risk matrix were used to provide insight into the experiences of boat operators. Reasons for mechanical shaft seal failure causing boat mishaps was investigated using one hundred and six (106) responses from respondents and the Cronbach's alpha of reliability of the three (3) cases was 0.9680, which indicated an excellent internal consistency among the three (3) cases with minimum measured error. Consequences of boat mechanical shaft seal were: Operational efficiency 36.8%, Financial performance 21.7%, crew well-being and impact on environmental safety 19.8%. The contributing factor to boat mishaps recorded the quality of material of the seal 32.1% and maintenance practices at 17.9%. The study showed that the root cause of Boat Mishap is caused by Mechanical factor (operational efficiency) at 36.8%: Engine malfunction which is as a result of faulty mechanical shaft seal and can be eradicated using non-faulty impeller and non-faulty mechanical shaft seal using a good maintenance practice.

Keywords — **Mechanical shaft seal, Boat Mishap, Risk Matrix, Failure Analysis, Impeller.**

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I. INTRODUCTION

The large expanse of water ways in the Niger Delta region have made boat transportation popular. The accidents caused by boat transportation have been investigated following the trends and considering the risk factors which encouraged militancy. Movement activities using passenger boats under human related factors such as over speeding, may be reasons for boat mishaps on in land water ways (Ukoji V.N.et al., 2015). Some suggested solutions to boat mishaps are: safety practices of wearing life jackets, enforcement of boat insurance policy and eradicating mechanical failures such as faulty mechanical shaft seals that cause boat mishaps (Olusegun.O.A.et al.,2023).

1.1Mechanical shaft seal

Mechanical seals are used to control leakages from centrifugal pumps and boat engines. They also isolate the shaft housing from the process fluid and reduce leakage to the surrounding marine environment. Before mechanical seals were invented, packing was used to control the leakage of process fluid into the marine environment (Qi et al., 2019). However, packing leakage rate was too high and if the packing was not maintained properly, it could result in scouring of the shaft and loss of packing material. This would accelerate the leakage rate and cause the seal to fail. The inherent problems associated with the packing caused industries to

Look for a more reliable and efficient way to control process fluid leakages in Boats. These necessities led to the invention of the mechanical shaft seal (Borras et al., 2020).

The introduction of mechanical shaft seals to control process fluid leakage made the use of packing less desirable.Packing became increasingly unacceptable when the leakage rate of the process fluid from packing is compared to that from a mechanical shaft seal. The ratio between packing and mechanical shaft seal leakage rate is 800:1 respectively. Furthermore, packing increased the power requirement by a ratio of 6:1 when compared with mechanical shaft seals. With the restrictions placed on process industries, factories and manufacturers by the Environmental Protection Agency (E.P.A.),the Occupational Health and Safety Association (O.H.S.A.) and the economic implications of the process fluid loss coupled with downtime as well as workers safety, have been instrumental in the development of a mechanical shaft seal in favor of packing. The development of a mechanical shaft seal that could be more efficient in leakage prevention and have a longer service life had thus become extremely crucial (Li et al., 2019; Zhang et al., 2018).

A seal is a mechanically loaded device consisting of rotating andstatic members, having lapped faces operating in close proximity under hydraulic load, used to minimize the leakage between a rotating shaft and a stationary housing (Borras et al., 2020).

II . METHODOLOGY

Failure analysis was carried out using some common factors of prevalence of failure in boat mechanical seal. Factors such as leakages in the seals, excessive wear and tear in the seals, errors in the installation of the seals, corrosion problems and degradation were looked into. The survey also looked into contributory factors that lead to failure in mechanical shaft seal. Some of the factors were the Quality of the seal,

Maintenance practices used, Environmental conditions and procedures for installing mechanical seals in Boats. When these Seal fail, what will be the consequences of failure?

2.1 Sources of Data

2.1.1 Primary Data:

Surveys

2.1.2 Secondary Data:

Existing literature, papers, and case studies pertaining to Boat mishaps, mechanical shaft seal and Boat engine.

2.1.3 Tertiary Data: Additional information provided by tertiary sources, such as government publications on manufacturing standards of Boats and failure analysis on boats seals.

2.2 Data Analysis

Data analysis were carried out using Failure analysis ad Risk matrix. The following tools were used in analysing the collected data:

2.2.1 Failure analysis

2.2.2 Risk matrix

A risk matrix was used to identify the risk, assess the risk impact of three cases of three Boat engine faults namely: CASE A: Impeller fouling, CASE B: Air cooler blockage ad CASE C: Filter fouling fault of Boat engines. The risk matrix was designed give informed decision of risk impact of the faults. A 5x5 risk matrix showing likelihood of risk, in high, low ad medium assessment was used. It was used to identify the risk, evaluate the risk and manage the risk in a systematic and structured manner I order to give informed decision of risk impact.

A statistical technique called cronbach alpha was used to check for consistency of the factors considered.

2.3 Validity and Reliability

The survey tools were pre-tested using a small sample of respondents in a pilot study to guarantee reliability. The survey's internal consistency was evaluated to guarantee accurate measurement across various items. Test-retest procedures were used to confirm reliability, guaranteeing that results remain consistent throughout several administrations. To ensure validity, Boat operators in oporoza community specialists in water ways, examined the survey questions and risk matrix procedures to verify their correctness and applicability. Wang and Park (2023).

2.4 Ethical Considerations

All participants were provided with informed consent before participating in the survey, ensuring confidentiality and voluntary involvement. The study complied with data protection regulations to safeguard respondents' privacy and sensitive water way information.

III RESULTS AND DISCUSSION

3.0 Data Presentation

The data presented showed an analysis of the surveyed questionnaire from marine operators as participants to provide insight into their experience with mechanical shaft seal failure, collating the needed data for shaft seal failure analysis. A real-time experimental data collection was done on a boat engine, by simulating likely faults such as filter fouling, air cooler blockage, and impeller fouling to determine variations in engine parameters and record to evaluate the potential effect on the mechanical shaft seal of the engine.

3.1 Information Analysis of Boat Mechanical Shaft Seal Failure

The information analysis of boat mechanical shaft seal failure was determined by three (3) factors such as the Prevalence Boat Shaft Seal Failures, Contributing factors to boat mechanical Shaft Seal Failure, and consequences of boat mechanical Shaft Seal as administered in questionnaire with one hundred and six (106) responses, the cronbach,s alpha of reliability of the three (3) items is 0.9680,

which indicates an excellent internal consistencies among the three (3) items with minimum measured error as shown in Table 1.1.

Table 1.1 Case Processing Summary and Reliability Statistics.

Description	Number of responses	%	Cronbach's Alpha	Number of Items
Valid Cases	104	98.1	0.9680	3
Excluded	2	1.9		
Total	106	100.0		

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3.2 Prevalence of Boat Mechanical Shaft Seal Failures

The prevalence boat Mechanical shaft seal failure were analysed with common factors contributing to boat mechanical shaft seal failure, such as leakages, excessive wear, installation errors, corrosion other inform of material degradation. This research work revealed that leakage with **27.4% of 29** cases and excessive wear with **20.8%** of cases as shown in Table 1.1, are the most prevalent factors, consistent with studies that highlight the important of seal integrity (Ben et al.,2017) that seal leakage and excess wear contributes serious to performance deficit and engine failure. Other significant factors with less impact are corrosion **17.9%,** material degradation **17.95 %,** and installation error **14.2%,** with the lowest tendency of mechanical shaft seal failure as emphasized in the need for a proper installation procedure (International Organization for Standardization, 2015)

Table 1.2**:** Data Summary of Prevalence of Boat Mechanical Shaft Seal Failures Factors

Factors description		Frequency	Percent	Valid Percent	Cumulative Percent
Valid	Leakages	29	27.4	27.9	27.9
	Excessive Wear	22	20.8	21.2	49.0
	Installation Errors	15	14.2	14.4	63.5
	Corrosion	19	17.9	18.3	81.7
	Other(Material Degradation	19	17.9	18.3	100.0
	Total	104	98.1	100.0	
Missing	System	2	1.9		
Total		106	100.0		

3.3 Contributing Factors to Boat Mechanical Shaft Seal Failure

The contributing factors to the failure of mechanical shaft seals in a boat are analysed with four basic factors: material quality, maintenance practice, environmental conditions, and installation procedures, with 106 responses from questionnaires. The results are categorized and quantified in terms of frequency and percentage in

Table1.2, also highlighting significant areas of concern. The material quality of **32.1%** is the predominant factor, accounting for over a third of the whole responses. This indicates that poor quality of material selection can lead to faster deterioration under operational stresses, resulting in premature seal failures. The choice of material, especially in marine applications, greatly influences the performance and longevity of mechanical components (Gidden, 2006). The environmental conditions and installation procedures have an equal percentage result of **20.8%,** meaning that seals are

likely exposed to harsh conditions such as seawater exposure, temperature fluctuations, and humidity, which can cause corrosion, swelling, or degradation of seals, ultimately leading to failure (Siti et al., 2016).

The installation procedure emphasizes the importance of proper installation as a preventive measure against mechanical shaft seal failure. Incorrect installation techniques, such as improper alignment or sealing methods, can lead to mechanical failure. As previously mentioned by Brown & Green (2019). Maintenance practices are **17.9%** present as a significant factor but a lesser contributor, while maintenance is essential for extending the life span of mechanical components, it appears that it cannot alone compensate for failing in material quality or installation procedure (Kimera et al., 2020). Other factors of **6.6%** with the least percentage. Further research could provide insights into these less-understood factors, potentially uncovering specific scenarios or operational practices that could contribute to mechanical shaft seal failure.

Table 1.4 Engine Parameters for Air Filter Fouled

	Case B	Percentage of air filter fouled.				
S/N	**Main Engine Parameters**	0%	10%	20%	30%	40%
1	Main Engine Inlet Temperature (ºC)	3.16	31.70	31.80	32.40	32.70
2	Turbo Charger Air Filter Pressure (mm/Wc)	192.62	248.57	285.50	285.66	286.25
3	Scavenge Air Inlet Temperature (oC)	181.12	173.49	165.57	141.51	124.46
4	Scavenge Air Pressure mm/Wc	205.27	200.66	194.62	153.53	110.47
5	Scavenge Air Temperature Manifold (oC)	37.90	36.50	36.20	35.90	35.90
6	Main Engine Scavenge Air Pressure (Bar)	2.26	1.99	1.77	1.41	1.31
7	Main Engine Average Cylinder Exhaust Temperature (Oc)	258.49	274.44	292.48	353.55	484.33
8	Exhaust Air Outlet Temperature (Oc)	200.82	219.88	241.47	315.62	456.35
9	Turbo Charger Turbine Inlet Temperature (Oc)	323.49	336.48	351.48	405.67	530.47
10	Turbo Charger Turbine Inlet Pressure (Bar)	1.90	1.70	1.50	1.20	0.91
11	Turbo Charger rpm (r/min)	13,329	13,240	13,442	12,537	11,478
12	Main Engine rpm (r/min)	96.60	96.60	96.60	96.60	96.50
13	Main Engine Fuel Load (%)	84.48	84.48	84.48	84.51	84.55

Case B had main Engine parameters with Temperature at 20% air filter fouled at 31.80 ºC , air filter pressure at 285.50 mm/Wc, scavenge air inlet temperature at 181.12 ºC. Main Engine Scavenge Air Pressure was recorded at 2.26 Bar.

Table 1.3**:** Data Summary of Contributing Factors

+		Frequency	Percent	Valid %	Cumulative Percent
Valid	Material Quality	34	32.1	32.7	32.7
	Maintenance Practice	19	17.9	18.3	51.0
	Environmental Conditions	22	20.8	21.2	72.1
	Installation Procedures	22	20.8	21.2	93.3
	Other	7	6.6	6.7	100.0
	Total	104	98.1	100.0	
Missing	System	2	1.9		
Total		106	100.0		

Factors to Boat Mechanical Shaft Seal Failure

3.5 Consequences of Boat Mechanical Shaft Seal Failure

The failure of a boat's mechanical shaft seal is critical in maritime operations; the analysis is based on four significant factors according to this research work, which are impact environmental safety, operational efficiency, financial performance, and crew well-being. The questionnaire respondents were 106, with 2 missing data points, and 104 valid cases.

Environmental Hazard of **19.8%** described shaft failure leading to leaks that posed a significant risk to the marine environment, potentially resulting in contamination and destruction of the local ecosystem (National Academies of Science, Engineering, and Medicine, 2024). Operational downtime with **36.8%** is a critical consequence of mechanical shaft seal failure in boats and other marine equipment, causing disruptions in boat schedules, loss of operational capacity, and increased maintenance time. Financial loss is the second most crucial consequence, with **21.7%** of boat mechanical shaft seal failure, which repercussion arose from repair cost, loss of revenue due to downtime, and potential fines for environmental violations (Wichelns & Oster 2006). Impact on crew safety, representing **19.8%** of the consequences, indicating significant risk to personnel working on board vessels, seal failure may expose crew members to hazardous conditions, which could lead to accidents or health risks. This highlighted the necessity for comprehensive safety training and emergency preparedness alongside regular maintenance.

3.6 Simulation Experimental Failure Analysis

The simulation of three cases informs of A: impeller fouled, B: Air flow fouled, and C: Cooler Tube Blockage. Engine parameters were recorded and analyzed for scavenge air pressure and temperature, turbocharger performance, and engine rpm and fuel load to critically determine the case that elevate mechanical shaft seal failure.

4.0 Failure Analysis of Case A

The simulation result of Case A, impeller fouled, the engine parameters are recorded.The impeller fouling ranged from 0 to 90%, at intervals of 25%, to determine scavenges pressure-temperature effect, turbocharger performance, and main engine rpm-fuel load reactions.

4.1 Impact Severity Analyses of the three cases on the effect of Mechanical shaft seal failure

Considering the three cases: A, B and C, the impact severity analysis on the effect on mechanical shaft seal failure, appears in case B. Case B had the most drastic effect on mechanical shaft seal integrity. As the temperature increased up to 530.47degree centigrade and significant variations in scavenge air pressure may result in thermal stress and uneven wear leading to potential failure, this was also reported by (Andert J, et al,.2018). Case C also has a concerning effect due to rising temperatures, but the impact of case B was more severe, while case A has a less severe impact on shaft seal failure.

Table 1.5 5x5 risk rating Matrix

RISK ASSESSMENT MATRIX				
5Medium/ high	Medium/ high	High	High	high
4Low/medium	Medium/ high	Medium/ high	High	high
3Low/medium	Low/medium	Medium/ high	Medium /high	high
2Low	Low	Low/medium	Low/medium	Low/medium
1Low	Low	Low	Low/medium	Low/medium
1	2	3	4	5

Effect

Risk Matrix Analyses of the three cases on the effect of Mechanical shaft seal failure

The risk matrix analyses assessed the likelihood of occurrence, severity and the risk level as summarized in Table 1.4: The likelihood of mechanical shaft failure occurrence is high in case B, the likelihood is medium in case C, and Low in Case A. The severity of the failure is critical for Case B, moderate for Case A, and significant for Case C. The risk level for Case B is higher due to extreme conditions, Case A has relatively low risk, and Case C poses a moderate risk with rising temperature.

Table 1.4 Risk Matrix Summary of the three Cases

Case	Likelihood Of Failure	Severity Of Failure	Risk Level
A	Low	Moderate	Low
B	High	Critical	High
C	Medium	Significant	Medium

DISCUSSION

Engine speed and Fuel Load Under Impeller Fouling

The engine speed is expected to decreases with increase in percentage level of impeller fouling but remain constant at **96.9 r/min**. while the main engine inlet temperature increases to **267.52°C** as fouling increases, and also engine load remain constant at **84.4%** as the engine might require more fuel to maintain desired output due to the compromised air-fuel ratio created by reduced scavenging efficiency and turbocharger performance (Seungchul, et, al,.2021), thus it could show increased fuel consumption to sustain overall engine performance level. Therefore, an impeller in good working conditions, will keep the seal from breaking to avoid leaks and fuel consumption from the engine of the boat.

IV CONCLUSION

The failure analysis of the mechanical shaft seal in the boat within Oporoza community Delta State, Nigeria has been successful examined; the

prevalence mechanical shaft failure is due to leakage with **29.7%** followed by excessive wear, installation error and corrosion according to this research findings, these issues largely arise from material degradation and poor maintenance.

Operational downtime of **36.8%** is the most consequential result of the mechanical shaft seal, which leads to a loss of financial gain. Other consequences are environmental hazards and health risks to the crew on board inform of contamination.

Mitigation Strategies for Case B given high impact severity scores, immediate attention should be directed towards understanding the underlying cause of failure in Case B. Implementing robust maintenance practices, conducting regular inspections, and investing in high-quality seals could reduce the failure rate associated with impact.

Root-cause analysis should be thoroughly conducted for failure in both case B and case C to identify specific factors contributing to the severity scores, to generate guiding information for preventive measures.

Awareness and training are essential to ensure personnel involved in managing mechanical shaft seals are well-trained in recognizing potential failure indicators, particularly for cases B and C. Regular training sessions can enhance awareness and preparedness among staff.

Prioritizing these areas, organizations can enhance the reliability of mechanical shaft seals and minimize the impact severity associated with their respective failures.

The **objectives** pursued in this study were met.

Objective 1.

To Investigate information analysis of Boat mechanical shaft seal failure to reduce severity.

Considering benchmarking with industry standards and best practices related to mechanical shaft seal management. Engaging with industry experts or associations to provide insights that may help in further reducing the severity.

Information analysis showed that Four factors were responsible for mechanical shaft seal failure:

Environmental hazard

Operational downtime

Financial loss

Impact on crew safety

Objective 2.

To Investigate prevalence of boat mechanical shaft seal failures.

Common Factors

Leakages 27.4%

Excessive wear 20.8%

Installation error 14.2%

Corrosion 17.9%

Material degradation 17.95%

Objective 3.

Establish contributing factor to boat mechanical shaft seal failure

Contributing factors

Material quality 32.1%

Maintenance practice 17.9%

Environmental conditions 20.8%

Installation procedure 6.6%

Objective 4.

Establish consequences of boat mechanical shaft seal failure

Impact environmental safety 19.8%

Operational efficiency 36.8%

Financial performance 21.7%

Crew well- being 19.8%

Objective 5.

Determine Engine parameters from simulation experimental analysis, three cases: From risk matrix, choose the low risk.

Case A: Impeller fouled

Case B: Air flow fouled

Case C: Cooler tube blockage, that elevate mechanical shaft seal failure.

The simulation of severity impact analysis on different cases of shaft seal failure demonstrates that **Case A:** Impeller fouled, has lowest impact severity

with the score around two 2 downward, indicating that failures in this case are less critical and may involve lower-risk operations, while Case C: cooler tube blockage with in score range of 3 to 5 shows a moderate level of impact severity, suggesting that they are not severe as those noted in **Case B: Air flow fouled, with the highest impact** severity attributed to **Case B** the severity score ranged between the severity score 5 to 10, indicating that **failure in this instance are most detrimental**. This could imply that the operation relating to Case B may be more complex or **involve higher risks** and the costs associated with this failure is high.

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