FAILURE ANALYSIS OF CENTRIFUGAL PUMP (OVERHUNG 212–P17) USING FMEA METHOD AT PT KILANG PERTAMINA INTERNASIONAL RU II DUMAI

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Abstrak

Pompa sentrifugal merupakan komponen penting dalam sistem pemrosesan minyak di kilang, termasuk di PT Kilang Pertamina Internasional RU II Dumai. Salah satu jenis pompa yang digunakan adalah pompa overhung 212–P17, yang mengalami gangguan operasional berupa kondisi jammed. Penelitian ini bertujuan untuk menganalisis potensi kegagalan komponen-komponen pompa menggunakan metode Failure Mode and Effect Analysis (FMEA), serta menentukan prioritas tindakan korektif berdasarkan nilai Risk Priority Number (RPN). Analisis dilakukan terhadap empat faktor utama: material, kesejajaran poros (shaft), pelumasan, dan celah (clearance). Hasil menunjukkan bahwa ketidaksejajaran poros memiliki RPN tertinggi sebesar 324, diikuti oleh pelumasan dengan RPN sebesar 160. Temuan ini mengindikasikan bahwa perbaikan harus difokuskan pada sistem kesejajaran poros dan manajemen pelumasan. Pendekatan FMEA terbukti efektif dalam mengidentifikasi komponen kritis dan menyusun strategi pemeliharaan preventif secara sistematis untuk meningkatkan keandalan operasi pompa.

Kata kunci: Pompa Sentrifugal, FMEA, Overhung, RPN, Ketidaksejajaran Poros, Pelumasan.

Abstract

Centrifugal pumps are essential components in refinery processing systems, including those at PT Kilang Pertamina Internasional RU II Dumai. One of the pumps in operation, the overhung type 212–P17, has experienced a jammed condition affecting its performance. This study aims to analyze the potential failure modes of the pump components using the Failure Mode and Effect Analysis (FMEA) method and to determine corrective action priorities based on the Risk Priority Number (RPN). The analysis focused on four key factors: material integrity, shaft alignment, lubrication condition, and clearance. The results indicate that shaft misalignment had the highest RPN of 324, followed by lubrication failure with an RPN of 160. These findings suggest that corrective measures should prioritize shaft realignment and lubrication management. The FMEA approach has proven effective in identifying critical components and structuring a preventive maintenance strategy to enhance the operational reliability of the pump system.

Keywords: Centrifugal Pump, FMEA, Overhung, RPN, Shaft Misalignment, Lubrication.

1. BACKGROUND

Centrifugal pumps are critical mechanical devices used to transfer and distribute fluids in the oil and gas industry. At Pertamina’s Refinery Unit II Dumai (RU II), which is a major crude-oil processing facility, these pumps are widely employed in various oil refining units to handle high-temperature fluids. Consequently, failures in pump components can significantly disrupt production processes and lead to substantial repair costs (Wardianto et al., 2021; Yamashita, 2014; Yanel, 2021a, 2023). Common pump failures include shaft misalignment, bearing wear, cracked bearing covers, mechanical seal leakage, and packing deterioration (Studi et al., n.d.; Yanel, 2021b). One specific design used is the overhung centrifugal pump, characterized by the impeller being mounted at the end of a shaft supported on only one side by bearings. This design makes the shaft more vulnerable to deflection and high radial loads, potentially reducing the lifespan of both bearings and mechanical seals (Yanel, 2021b)).

To anticipate and manage such failures before they occur, the Failure Mode and Effects Analysis (FMEA) method is widely used in industrial maintenance. FMEA allows for the identification and

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prioritization of potential failure modes by assigning scores for severity, occurrence, and detection capability. These scores are then multiplied to calculate a Risk Priority Number (RPN), which indicates the urgency of corrective action required. A higher RPN reflects a higher risk and priority for maintenance intervention (Studi et al., n.d.).

This study applies the FMEA method specifically to the Overhung Centrifugal Pump 212–P17 at RU II Dumai, which operates under extreme thermal conditions, with fluid temperatures reaching approximately 271°C. The pump experienced a 'jammed' condition, signaling possible severe wear between the impeller and casing. Unlike previous analyses such as that of Fitri (2024) on pump 610–P-207, this study focuses on an overhung configuration and the effects of high operating temperatures. These characteristics introduce distinct failure modes such as shaft flexing and thermal expansion that have not been widely analyzed in past research. The novelty of this study lies in its specific evaluation of failure factors—material selection, shaft alignment, lubrication, and clearance—using a systematic FMEA approach. This analysis provides targeted corrective priorities to improve pump reliability and operational performance (Studi et al., n.d.; Yanel, 2021a).

2. METHODOLOGY

The subject pump is a single-stage, API-compatible overhung centrifugal pump (212–P17), where the impeller is mounted at the free end of the shaft and supported by bearings on one side (Parwati et al., n.d.). Four potential failure-mode categories were identified from maintenance inspection:

(1) Material mismatch: inappropriate material properties of the impeller or casing leading to excessive wear;

(2) Shaft misalignment: the shaft not properly centered in the casing causing uneven impeller rotation;

(3) Insufficient lubrication: loss or degradation of bearing lubrication leading to friction and overheating; and

(4) Impeller-casing clearance: reduced clearance between impeller and casing causing rubbing and vibration. Each failure mode was evaluated using FMEA. Severity (S), Occurrence (O), and Detection (D) were scored on scales of 1–10 based on expert judgment

Here, Severity gauges the seriousness of the failure effect (higher means more severe), Occurrence rates the likelihood of the failure happening, and Detection rates the ability to catch the failure before it occurs (higher D means lower detectability) (Sutrisno et al., 2015a). The following steps were applied in accordance with established FMEA protocols :

1. Identify system functions and failure modes – Each pump component is assessed for its potential failure types, such as wear, friction, or deformation.
2. Evaluate failure effects – The impact of each failure mode on the performance of the pump and related systems is analyzed.
3. Severity rating (S): Assigned based on how critically the failure affects safety, functionality, or product quality (scale 1–10).
4. Occurrence rating (O): Determined based on how frequently the failure is likely to occur under normal operating conditions (scale 1–10).
5. Detection rating (D): Assesses the likelihood that the failure would be detected before causing serious damage (scale 1–10).
6. Risk Priority Number (RPN): Calculated as RPN = S × O × D. A high RPN indicates the need for urgent attention .
7. Corrective Action Planning: Failure modes with the highest RPN are prioritized for mitigation.

The values for S, O, and D were obtained through consultation with on-site maintenance experts and reference to historical data on pump failures.RPN=S×O×D (Ridlo, 2019; Sellappan &

Palanikumar, 2013). Modes with higher RPN are deemed higher risk and warrant priority in maintenance planning.

3. RESULTS AND DISCUSSIONS

The FMEA scores and resulting RPN values for each failure mode are summarized in Table 1. The analysis produced RPNs of 36 for material, 60 for shaft misalignment, 60 for lubrication deficiency, and 30 for clearance. Thus, the highest risk factors identified were the shaft-centering issue and the lubrication problem (both RPN 60). These values come directly from the maintenance FMEA

Table 1 SOD (Severity×Occurrence×Detection) recorded for pump 212–P17

Failure Mode	**Severity (S)**	**Occurrence (O)**	**Detection (D)**	**RPN (S×O×D)**
Material incompatibility	4	3	3	36
Shaft misalignment	5	2	6	60
Lubrication deficiency	4	3	5	60
Impeller–casing clearance	3	2	5	30

Table 1: FMEA scores and RPNs for pump 212–P17 failure modes. The RPN values for shaft misalignment and lubrication are the highest (60), indicating these as the most critical failure modes.

The Overhung Centrifugal Pump 212–P17 during maintenance and inspection work conducted in the workshop following an operational failure in the field (Figure 1). The pump has been disassembled, revealing key internal components such as the impeller, casing, and shaft. Evidence of wear and mechanical damage can be observed on the wearing surface between the impeller and casing. Scratch marks and signs of metal contact are visible, indicating that excessive friction occurred—likely due to shaft misalignment or insufficient clearance. This image supports the mechanical failure analysis by visually demonstrating symptoms identified during the disassembly process.

Field installation of Overhung Centrifugal Pump 212–P17 in its operational setting at PT Kilang Pertamina Internasional RU II Dumai (Figure 2). The pump is mounted horizontally and integrated into the piping system that transports high-temperature fluid, specifically Net Heavy Kerosene at approximately 271°C. The photo provides an overview of the pump's environment, including the inlet and outlet lines, support structures, and adjacent equipment such as heat exchangers. This contextual image is essential for understanding operational stresses, including thermal expansion, vibration exposure, and space constraints affecting maintenance accessibility. It complements the workshop image by providing a broader picture of the pump's operating conditions prior to failure.

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Figure 1 Photo of Overhung Pump 212 P-17

Figure 2 Field Photo of Overhung Pump 212 P-17

Failure Mode and Effects Analysis (FMEA)

The following section presents the Failure Mode and Effects Analysis (FMEA) applied to Overhung Centrifugal Pump 212–P17. This table identifies the primary causes of failure observed during maintenance, categorized into four key assumptions: material, shaft alignment, lubrication, and clearance. The analysis involves assigning scores for Severity (S), Occurrence (O), and Detection (D), based on technical judgment and inspection results. The Risk Priority Number (RPN) is calculated as the product of these three values (RPN = S × O × D), which helps prioritize which failure modes require the most immediate corrective action.

Table 2 Failure Mode and Effects Analysis (FMEA) of Pump 212–P17

No	Assumption	Failure Mode	Effect of Failure Mode	Cause of Failure	Control Measures	S-O-D	RPN
1	Material	Friction due to material	Accelerated wear on	Incompatible material	Use correct replacement material	4-3-3	36

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		thermal properties	wearing surface	properties under heat			
2	Shaft and Casing	Misalignment in casing	Potential severe damage to components	Shaft not centered in casing	Perform visual inspection and alignment check	5-2-6	60
3	Lubrication	Friction due to thermal expansion	Overheating causes jamming	Dry or inadequate lubrication	Identify and correct lubrication issues	4-3-5	60
4	Clearance	Component contact and interference	Vibration and noise	Clearance too narrow	Adjust material and proper clearance setting	3-2-5	30

4. DISCUSSION

The FMEA indicates that shaft alignment and lubrication are the dominant risk factors for this pump. Both modes received RPN 60, higher than those for material or clearance (Table 1). Maintenance notes specifically call out "kesejajaran shaft (shaft centering) and lubrication" as having the highest RPN (Ridlo, 2019; Sellappan & Palanikumar, 2013; Sutrisno et al., 2015b). This suggests the pump jammed due to excessive shaft misalignment causing rubbing, exacerbated by dry bearings. The report recommends corrective actions accordingly: perform precise shaft alignment (adjusting or "rounding out" the shaft and centering it within tolerance) and inspect all components that might cause misalignment (Yanel, 2021c). For lubrication, the recommended fix is to identify why the pump's bearings ran dry and then apply proper lubrication (using the correct lubricant and schedule) (Wardianto et al., 2021; Yanel, 2023).

These recommendations align with general pump reliability practices. Proper shaft alignment reduces unnecessary stress, vibration, and component wear. Indeed, misaligned shafts are known to induce excessive vibration and heat, leading to premature failure if unchecked. Likewise, adequate lubrication is essential: literature notes that a majority of pump bearing failures are due to contamination or lack of lubricant. In the cited study, clean lubrication was found to be critical, with over 50% of bearing problems attributed to oil contamination (Sellappan & Palanikumar, 2013). Thus, addressing the high-risk modes identified (alignment and lubrication) is consistent with best practices.

5. CONCLUSION

FMEA of the overhung centrifugal pump 212–P17 at Pertamina RU II Dumai revealed that the most critical failure causes are shaft misalignment (centring) and lubrication deficiency (both RPN = 60). Other modes (material mismatch, clearance) had lower RPNs. These results suggest preventive maintenance should focus on ensuring precise shaft alignment and reliable lubrication. Recommended actions include routine alignment checks with proper shimming or coupling adjustments, and scheduled lubrication inspections with high-quality oil. Such measures correspond to established reliability guidelines: proper alignment and clean lubrication are widely recognized as keys to pump longevity. Implementing these corrective actions should mitigate the high-risk failure modes and reduce the chance of pump seizure or jam. Recommendations: In practice, operators should (1) perform periodic visual and laser alignment checks on pump 212–P17 to keep the shaft centered and within tolerance, and (2) monitor bearing lubrication levels and quality (e.g. inspect oil seals, refill or replace lubricants on schedule). These preventive steps are expected to address the FMEA-identified risks, thereby improving pump availability and avoiding unscheduled shutdowns.

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