

Enhancing Reliability and Maintenance Efficiency of Screw Press Machines in Palm Fruitlet Processing Mills: A Failure Mode and Effect Analysis (FMEA) Approach

Abbiyu Bima Aditya¹, Bagus Nugroho², Hermantoro¹, Rengga Arnalis Renjani^{1*}

¹Department of Agricultural Engineering, Stiper Agricultural University (INSTIPER), Yogyakarta, Indonesia

²Akademi Komunitas Perkebunan Yogyakarta, Indonesia

*Corresponding author: rengga_tepins@instiperjogja.ac.id

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ABSTRACT

This study analyzed the reliability and failure risks of screw press machine components in a palm oil loose fruit mill using the Failure Mode and Effect Analysis (FMEA) method. The objective was to identify critical components, evaluate their Risk Priority Number (RPN), and propose appropriate maintenance strategies. Data were collected through questionnaires, field observations, and maintenance records. The RPN was calculated by multiplying severity, occurrence, and detection scores, while reliability was assessed using the Mean Time Between Failures (MTBF) formula. The worm screw showed the highest RPN at 252, indicating a critical risk level, while the press cage followed with an RPN of 210. MTBF analysis revealed that the worm screw required replacement every 313.5 hours, whereas components like the V-belt and electro motor had longer MTBF intervals of up to 3135 hours. The findings suggested that targeted maintenance on high-risk components could reduce downtime and enhance production efficiency. This study concluded that prioritizing preventive maintenance based on RPN and MTBF results was crucial for maintaining the operational performance of screw press machines in palm oil processing.

Keywords: Failure mode and effect analysis, mean time between failures, palm oil, screw press machine, workshop management

INTRODUCTION

Palm fruitlet mills (PFMs) are critical industrial facilities that processed oil palm loose fruits into crude palm oil (CPO) (Renjani et al., 2020). These loose fruits, separated from the bunches during harvesting, and the residual fruits left unprocessed in the fresh fruit bunch (FFB) mills, served as the primary raw materials for CPO

production (Smed & Athaillah., 2023). The processing stages in these mills included sterilization and the extraction of oil using screw press machines (Fadhilah et al., 2024). The screw press functioned as a crucial tool for extracting undiluted crude oil (UNCO) from the mashed palm fruit through the pressing process (Taringan &

Sinaga, 2020).

Palm fruitlet mills played a significant role in reducing waste and improving production efficiency. However, they often faced challenges related to frequent breakdowns of machinery, particularly the screw press machines, which disrupted operations and decreased productivity. In an era of increasing industrial competition, companies had to improve productivity and implement efficiency measures across various production processes. Machines were vital components in production processes, playing a critical role in ensuring smooth operations (Amalia et al., 2022). According to Praharsi et al. (2015), prolonged use of machinery led to performance degradation, which hampered production, increased the risk of workplace accidents, and incurred substantial losses for companies. Hence, it was crucial to ensure that production machines remained in optimal condition during operations. Maintenance was a crucial activity that aimed to ensure machinery and facilities remained in good working condition, enabling continuous operation to meet production targets (Syarifuddin et al., 2022).

In the context of palm fruitlet mills, applying Failure Mode and Effect Analysis (FMEA) was critical to identify the most vulnerable components of machines, such as the screw press. This allowed plant management to assess the risks associated with each component, prioritize maintenance

actions, and plan effective maintenance strategies. Maintenance was essential to ensure the proper functioning of plant equipment, make necessary repairs or replacements, and ensure that the production process remained smooth and aligned with production goals (Nur & Isranuri, 2021). This approach not only helped prevent unanticipated downtime but also enhanced operational efficiency and overall mill productivity. Therefore, FMEA served as an effective method to support maintenance operations in palm fruitlet mills (Pasaribu et al., 2021).

This research aimed to analyze the failure modes of screw press components in palm fruitlet mills using the FMEA method. The study identified potential production failures by calculating the Risk Priority Number (RPN) and determined the priority for repairs and maintenance based on the risk analysis of failure modes. While the Overall Equipment Effectiveness (OEE) method focused on assessing machine performance and operational efficiency after failures occurred (Syukra & Putri, 2024), FMEA excelled in preventing failures by providing a deeper risk analysis and identifying potential failures before they happened. Therefore, this study aimed to provide valuable insights for companies to improve the operational efficiency of screw press machines, minimize downtime, and enhance mill productivity, while also serving as a reference for future research in the same field.

MATERIALS AND METHODS

This research focused on a palm fruitlet mill (PFM) as the object of study. The main equipment and subjects of the study were the screw press components, specifically the Wang Yuen KKY P15 and Max Drive MAE P15 screw press machines. The tools used for data analysis included an Asus Core i3 7020U laptop with Microsoft Excel 2016.

This study was a descriptive research type, aimed at analyzing the failure modes of screw press machines in the palm fruitlet mill. The research instruments included a questionnaire used to collect data from the maintenance team at the mill. The data collected consisted of machine failure

records, component replacement data, machine operating hours, and questionnaire forms that gathered information from the maintenance team regarding the operational failure modes of the screw press machines, namely severity, occurrence, and detection (Setiawan, 2014).

Sampling was conducted by selecting respondents with experience and knowledge in machine maintenance, such as machine operators and technicians who had worked for at least five years at the palm fruitlet mill. Data were collected through field observations, interviews, and the completion of FMEA questionnaires. The collected questionnaire data were then used to calculate the

Risk Priority Number (RPN) and to provide recommendations for appropriate maintenance actions for the screw press machines based on the analysis results.

The reliability of the screw press was tested using the FMEA method. The risk level of each component was determined by calculating the RPN. The RPN was used to identify the failure risk level of each component of the screw press by multiplying three criteria: severity, occurrence, and detection (Rinoza & Kurniawan, 2021). The RPN can be calculated using the formula:

$$RPN = S \times O \times D \quad (1)$$

Where: RPN = Risk priority number; S = severity; O = occurrence; D = detection

In this study, the variables were determined through a questionnaire provided to six respondents related to the maintenance of the screw press. The values from the variables were used to measure the RPN scale for various components. The geometric mean (GM) of the questionnaire results was calculated using the following formula:

$$GM = \sqrt[n]{x^1 \times x^2 \times \dots \times x^n} \quad (2)$$

Where: GM = Geometric mean; n = number of data points; x = respondents

Mean Time Between Failure (MTBF) was defined as an indicator of the reliability of a machine (Effendi & Ranguti, 2017). The MTBF calculation provided the average time that could be used as a reference for component replacement before a machine failure occurred. The MTBF value was calculated using the formula:

$$M_t = \frac{O_t}{F} \quad (3)$$

Where: Mt = Mean time between failure; Ot = operating time, or the total machine operational hours without failure during the observation period; F = number of machine failures that occurred during the study period.

The failure mode data (Table 1) shows the mechanisms that can cause failure in a component or process, which include various conditions that disrupt the system's function in palm oil processing at the loose fruit mill. Identifying failure modes is the first step in FMEA analysis.

Table1. Failure mode for each component in the screw press

Component	Failure mode
Worm screw	There is wear on the screw surface
Press cage	Press cage worn
V-belt	Deformation of rubber belt
Rubber flexible coupling	Rubber coupling worn
Electro motor	Burnt insulation (Short)
Oil seal	Oil seal damage
Lightening shaft	Wear on shaft

RESULTS AND DISCUSSION

Severity Values

The identified failure modes result in assessments from six respondents. The evaluation is conducted for each variable: severity, occurrence, and detection. Table 2 shows the severity values for different failure modes on screw press machine components. The worm screw

experiences wear on the screw surface, which causes the loss of main function and triggers an alert, thus receiving a severity value of 9. The press cage damage also receives a severity value of 9, as it reduces the main function of the machine, although it does not directly trigger an alert. Both components require serious attention in maintenance to prevent further operational

disruption (Haq et al., 2021).

The V-belt, which experiences deformation on the rubber belt, is given a severity value of 6. This damage reduces the comfort and operational functionality of the machine, but does not directly affect the main function. The worn coupling on the rubber coupling receives a severity value of 8, indicating a reduction in the main function, although it does not cause critical damage to the system. Both components still require maintenance attention (Setiawan, 2014).

The electro motor, with burnt insulation (short), receives a severity value of 8, indicating that this damage can stop the machine's operation,

thus requiring immediate replacement. The damaged oil seal receives a severity value of 8 because it reduces the main function of the machine and affects operational efficiency. The lightening shaft, which experiences wear, gets a severity value of 7, as this damage only reduces operational comfort and does not directly affect the machine's main function. Overall, components with high severity values such as the worm screw, press cage, and electro motor require more attention to ensure the smooth operation of the machine and to prevent greater damage (Syarifuddin et al., 2022).

Tabel 2. Results of severity values and geometric mean severity

Component	Failure Mode	Criteria of Severity	Respondent						Scale
			1	2	3	4	5	6	
Worm screw	There is wear on the screw surface	Loses the main function and raises an alert	9	9	9	8	9	8	9
Press cage	Press cage worn	Reduction of main functions	9	9	6	9	7	3	7
V-belt	Deformation of rubber belt	Reduces comfort and functionality of use	6	7	6	4	4	7	5
Coupling	Rubber coupling worn	Reduction of main functions	8	7	6	8	8	7	7
Electro motor	Burnt insulation (Short)	Loss of main function	8	9	9	8	8	7	8
Oil seal	Oil seal damage	Reduction of main functions	8	9	6	7	7	6	7
Lightening shaft	Wear on shaft	Loss of comfort of use function	7	7	6	6	7	6	6

Occurrence Values

Table 3 shows the occurrence scale for damage to screw press machine components based on machine operating hours (Setiawan, 2014). Based on the analysis, damage to the worm screw occurs at scale 7, which is between 101-401 machine operating hours. This damage is caused by high friction due to foreign materials, such as sand and loose fruit waste, entering the machine without proper cleaning. According to the analysis, the

worm screw at the loose fruit mill needs to be replaced after reaching 313.5 machine operating hours. Wear on the press cage is caused by excessive load and improper installation, leading to damage to the component. Damage to the press cage is rated on scale 6, occurring between 401-1000 machine operating hours, with replacement required after 627 hours of operation (Haq et al., 2021).

Table 3. Results of occurrence and geometric mean occurrence values

Component	Failure Mode	Probability of Occurrence (machine operating hours)	Respondent						Scale
			1	2	3	4	5	6	
Worm screw	There is wear on the screw surface	101-400	7	7	8	7	7	7	7
Press cage	Press cage worn	401-1000	7	6	6	6	7	6	6
V-belt	Deformation of rubber belt	1001-2000	5	5	5	6	5	7	5
Coupling	Rubber coupling worn	1001-2000	5	6	5	6	6	5	5
Electro motor	Burnt insulation (Short)	3001-6000	3	4	2	4	3	4	3
Oil seal	Oil seal damage	1001-2000	7	5	5	6	5	5	5
Lightening shaft	Wear on shaft	3001-6000	3	3	2	3	5	5	3

Deformation of the rubber belt, damage to the rubber coupling, and the oil seal all receive a score of scale 5, meaning that these damages occur within the range of 1001-2000 machine operating hours. Deformation of the rubber belt is caused by high operational speed and heavy load. The rubber belt should be replaced after 3135 hours of operation. Damage to the rubber coupling is caused by its function of bearing the load to prevent the flexible coupling from making contact, and it needs to be replaced after 783 hours of operation. The oil seal is damaged due to the entry of dirt and foreign particles, which causes a reduction in rotation, requiring replacement after 1567 hours of operation (Setiawan, 2014).

Damage to the electro motor occurs at scale 3, between 3001-6000 machine operating hours, caused by connected rotor and stator components, resulting in a fire. This damage occurs due to a delay in component replacement. The motor bearing at the loose fruit mill must be replaced after 3135 machine operating hours. Additionally, wear

on the shaft is rated at scale 3, occurring between 3001-6000 machine operating hours, caused by pressure and friction between the fiber and nut from the press, which affects the precision of the shaft system. The shaft component should also be replaced after 3135 machine operating hours. Although rated at scale 3, if this damage is ignored, it could cause the cessation of the palm oil processing operation at the loose fruit mill, which would directly impact productivity and production efficiency (Syarifuddin et al., 2022).

This indicate that damage to components such as the worm screw, press cage, and V-belt occurs more frequently during lower machine operating hours, while damage to components like the electro motor and shaft tends to happen at higher machine operating hours. Timely handling through component replacement is crucial to ensure smooth machine operation and prevent further losses due to unexpected downtime (Pasaribu et al., 2021).

Detection Values

Table 4 presents the detection levels for failure modes in screw press machine components. The assessment based on the "chance" of detection refers to the principles of risk management and effective maintenance. According to the analysis, damage to the worm screw has a relatively high detection chance with a score of 4. This damage is not immediately visible but can be identified through proper testing. The press cage has a very high detection chance with a score of 5, although it requires more complex detection procedures and is

not easily detected during routine inspections. The V-belt, which experiences deformation on the rubber belt, receives a detection score of 3, indicating that this damage can be detected through scheduled maintenance, although further testing is needed to accurately confirm the damage.

Damage to the coupling is rated with a score of 4, indicating a relatively high detection chance, although failure is not immediately visible and requires testing. Damage to the electro motor, caused by burnt insulation (short), results in the

machine stopping, and thus receives a score of 1, indicating that this damage is definitely detectable. The oil seal receives a detection score of 3, which means the damage can be detected through scheduled maintenance procedures, but further testing is necessary to confirm the extent of the

damage. Damage to the lightening shaft has a very high detection chance with a score of 2, as the damage can easily be identified through visual inspection and routine monitoring.

Table 4. Results of detection and geometric mean detection values

Component	Failure Mode	Detection Design Control	Respondent						Scale
			1	2	3	4	5	6	
Worm screw	There is wear on the screw surface	Quite a high chance of being detected	4	4	5	3	4	5	4
Press cage	Press cage worn	Medium chance of being detected	5	4	5	6	5	6	5
V-belt	Deformation of rubber belt	High chance of being detected	2	3	5	3	4	4	3
Coupling	Rubber coupling worn	Quite a high chance of being detected	5	5	4	3	4	4	4
Electro motor	Burnt insulation (Short)	Definitely detected	1	1	1	1	1	1	1
Oil seal	Oil seal damage	High chance of being detected	2	4	3	2	4	5	3
Lightening shaft	Wear on shaft	Very high chance of being detected	1	2	1	3	4	4	2

Components with high detection scores, such as the worm screw, press cage, and oil seal, require more complex detection procedures and further testing. In contrast, components like the electro motor and lightening shaft are easily detected with existing procedures. The

determination of these detection scores aligns with the risk management principles discussed by Haq et al. (2021), who emphasize the importance of detection evaluation in FMEA analysis to identify risks and determine appropriate corrective actions.

Risk Priority Number (RPN)

Table 5 presents the Risk Priority Number (RPN) values for screw press machine components, calculated by multiplying the severity, occurrence, and detection ratings. The resulting RPN values are compared to standard scale values: <60 for low, 60-80 for moderate, 80-100 for high, and >100 for critical (Haq et al., 2021). Several components have RPN values above 100, indicating a high to critical risk of failure.

The worm screw experiences wear on the screw surface due to friction from foreign materials like sand and loose waste. This failure has a

severity rating of 9, occurrence of 7, and detection of 4, resulting in a high RPN of 252, indicating significant consequences and the need for immediate attention (Setiawan, 2014). Another failure of the worm screw, caused by press cage wear and improper bearing mounting, results in non-optimal oil filtration. It has a severity of 7, occurrence of 6, and detection of 5, leading to an RPN of 210. This failure also poses risks to system efficiency and requires timely maintenance (Haq et al., 2021).

The press cage suffers damage due to deformation of the rubber belt caused by excessive

load and high speed. With a severity rating of 5, occurrence of 5, and detection of 3, it results in a moderate RPN of 75. This failure reduces machine efficiency and requires routine monitoring and maintenance.

The V-belt, damaged by a worn rubber coupling, affects the coupling's flexibility, with a severity rating of 7, occurrence of 5, and detection of 4, resulting in an RPN of 140. This failure

reduces power transmission efficiency, highlighting the need for early detection and maintenance. The coupling failure, caused by burnt insulation (short), occurs due to delayed motor bearing replacement. It has a severity of 8, occurrence of 3, and detection of 1, yielding a low RPN of 24. Despite the low occurrence, it requires prompt corrective action to avoid significant operational impact (Syarifuddin et al., 2022).

Table 5. Result of RPN calculation

Component	Failure Mode	Failure Cause	Failure Effect	S	O	D	RPN
Worm screw	There is wear on the screw surface	There is a lot of friction from foreign materials such as sand and loose rubbish	Unable to extract oil optimally	9	7	4	252
Worm screw	Press cage worn	Worn bearings and improper mounting position	Oil filtration is not optimal	7	6	5	210
Press cage	Deformation of rubber belt	Too high speed and too heavy load	Slippage occurs and the press machine rotation is not constant	5	5	3	75
V-belt	Rubber coupling worn	Hold the load so that the flexible coupling iron does not touch each other	There is friction in the flexible coupling iron, which reduces the efficiency of power transmission.	7	5	4	140
Coupling	Burnt insulation (Short)	Late replacement of motor bearings	The rotor and stator components are connected so that they burn out	8	3	1	24
Electro motor	Oil seal damage	Dirt and foreign particles enter the seal area	The rotation becomes low and the press capacity decreases.	7	5	3	105
Oil seal	Wear on shaft	There is friction between the fiber and the nut output from the press.	Pressure and friction affect the precision of the shaft system and interfere with operation.	6	3	2	36

Electro motor failure, caused by oil seal damage, occurs when dirt and foreign particles enter the seal area, leading to reduced rotation and decreased press capacity. It has a severity rating of 7, occurrence of 5, and detection of 3, resulting in an RPN of 105. Regular maintenance is essential to prevent performance issues. Oil seal failure due to wear on the shaft affects shaft precision and interferes with machine operation. This failure has a severity rating of 6, occurrence of 3, and detection of 2, leading to an RPN of 36. While less

critical, it still impacts operational efficiency and requires timely attention.

Components with high RPN values, such as the worm screw and press cage, need immediate attention due to their significant impact on system functionality. Regular maintenance is crucial to prevent further damage (Pasaribu et al., 2021). Components with higher RPN values show lower reliability (Marpaung et al., 2021). The worm screw, with an RPN above 100, is the most critical component, indicating the need for focused

maintenance (Darma et al., 2020). The RPN graph reveals that five components have very high-risk values, significantly impacting productivity. These components require extra maintenance to minimize

Mean Time Between Failures (MTBF)

Table 6 presents the MTBF for screw press machine components. The MTBF values are calculated by dividing the total operating time by the number of failures, indicating component reliability. The worm screw shows the lowest MTBF at 313.5 hours (21 days) due to 10 failures, suggesting frequent maintenance is needed (Syarifuddin et al., 2022).

The press cage has an MTBF of 627 hours (42 days) with 5 failures, requiring periodic attention. The coupling has a moderate MTBF of 783 hours (52 days), indicating a moderate failure rate. The oil seal demonstrates high reliability with

downtime risks (Yuhelson, 2010). Proper scheduling of maintenance, based on the Mean Time Between Failure (MTBF), helps maintain smooth operation and prevent critical failures.

an MTBF of 1567 hours (104 days), showing fewer failures. Both the V-belt and lightening shaft have an MTBF of 3135 hours (209 days), with only one failure each, indicating excellent reliability.

The electro motor also shows a high MTBF of 3135 hours (209 days), with only one recorded failure. These results highlight the components i.e: worm screw and press cage require more frequent maintenance, while components like the V-belt and electro motor are more reliable and require less attention (Setiawan, 2014). Regular monitoring is essential to ensure efficient machine operation.

Table 6. Results of MTBF calculation

Component	Working time (h)	Observation Period (Working Days)	Operating Time (h)	Number of Damages (times)	MTBF (h)	MTBF (days)
Worm screw	15	209	3135	10	313,5	21
Press cage	15	209	3135	5	627	42
Coupling	15	209	3135	4	783	52
Oil seal	15	209	3135	2	1567	104
V-belt	15	209	3135	1	3135	209
Lightening shaft	15	209	3135	1	3135	209
Electro motor	15	209	3135	1	3135	209

CONCLUSION

This study has evaluated the reliability and maintenance needs of various screw press machine components based on their Risk Priority Number (RPN) and Mean Time Between Failures (MTBF). The findings have shown that components such as the worm screw and press cage have higher RPN values, indicating a higher risk of failure and a need for more frequent maintenance. In contrast, the

electro motor, V-belt, and lightening shaft have demonstrated greater reliability with longer intervals between failures, as evidenced by their higher MTBF values, ranging from 209 to 104 days. The results have highlighted the importance of implementing regular and targeted maintenance practices to ensure optimal machine performance and minimize operational disruptions.

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