Failure Risk Analysis on Screw Compressor using Failure Mode and Effect Analysis (FMEA) Method

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Abstract: Screw compressor is a compressor that uses impeller media to compress air. This compressor is included in the type of rotary compressor. In the work process, the screw compressor is equipped with several supporting components. The screw compressor consists of 5 components, namely: intake filter, main motor, v-belt, screw compressor, and oil filter. To maintain the performance of the screw compressor, it requires a method that can predict the critical time in screw compressor components and can determine the impact of damage on an operation. In this study, qualitative analysis and quantitative analysis will be conducted to predict and determine the time and effect of screw compressor components failure. The method used in qualitative analysis is Failure Mode and Effect Analysis (FMEA) and Logic Tree Analysis (LTA) methods. While the quantitative analysis uses the reability function (Rt), hazard rate function (ht), and mean time to failure (MTTF) parameters. By using qualitative FMEA analysis, the repair priority order in the screw compressor is the oil filter, and oil filter is C category using LTA analysis, it means if the failure mode does not have an impact on safety or operational plant and only causes relatively small economic losses for repairs. While quantitative methods results recommended treatment time, intake filter must be maintained 25 - 27 days, oil filter must be maintained 28 - 29 days, V-belt must be maintained 105 - 125 days, the main motor must be maintained 330 - 335 days, and screw must be maintained 292 - 313 days.

1 INTRODUCTION

The screw compressor is a compressor that uses impeller media to compress air. This compressor is included in the type of rotary compressor. In the work process, the screw compressor is equipped with several supporting components. The main component of the screw compressor is two pieces of the screw, which rotate in the opposite direction, causing low pressure on the suction side and high pressure on the discharge side. Screw rounds are obtained from the main motor components distributed through the V-belt. To maintain its reliability, the screw compressor is equipped with an oil cooling system that can prevent overheating. In addition, the screw compressor is also equipped with an air filter that can prevent dust particles from entering the screw compressor system.

However, in the work process, screw compressors often experience several constraints on their components. The lightest obstacle experienced by screw compressors is the blockage of air-water by dust or dirt. This can cause a decrease in the amount of air entering the screw compressor. It can lead to a decrease in the efficiency of the screw compressor. Another obstacle that may occur is the clogging of the oil filter due to the dirt in the oil. This can lead to overheating so that it can reduce the performance of the screw compressor work system. The hardest obstacle found in a screw compressor is the damage in the main motor that can cause a decrease in screw rotation so that it can reduce the amount of compressed air. In addition, screw damage caused by the poor quality of fluid can decrease the efficiency of the screw compressor. To maintain the performance of the screw compressor, it requires a method that can predict the critical time in screw compressor components and can determine the impact of damage on an operation.

In this study, qualitative analysis and quantitative analysis will be conducted to predict and determine the time and effect of screw compressor components failure. The method used in qualitative analysis is Failure Mode and Effect Analysis (FMEA) and Logic

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Tree Analysis (LTA) methods. FMEA method is a failure analysis method to determine the level of damage so that the repair priority in a tool is known. While the LTA method is a method used to give priority to each damage mode and conduct a review toward functions and malfunctions. While the quantitative analysis uses the reability function (Rt), hazard rate function (ht), and mean time to failure (MTTF) parameters. The damage constant needed to get those three parameters above is obtained from the

Weibull 6 ++ software based on the data that has occurred.

From the analysis carried out, it is expected to be able to know the time of damage and the type of damage that occurs in screw compressor components. Therefore, it can determine the damaging impact of the screw compressor unit operating system and the correct repair

2 LITERATURE REVIEW

The screw compressor is a compressing or compressing fluid (gas or air) device with a screw-shaped cross-section. The screw compressor system uses a screw system, and the incoming air will be filtered using an air filter, then the air will enter the compressor inlet side. The air will spin following the screw compressor. Both screws in the compressor cause the air to compress so that at the outlet side, the air pressure will rise.

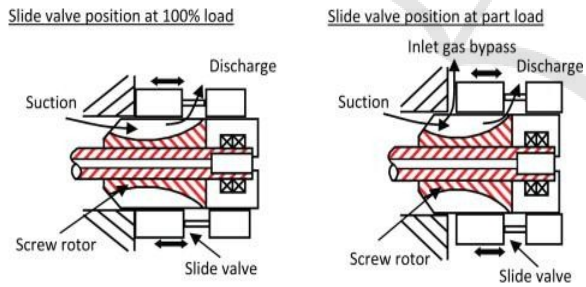

Figure 1. Component screw compressor

Based on picture 1 screw compressor component consists of 5 components, namely: intake filter, main motor, v-belt, screw compressor, and oil filter.

a. Intake Filter
The function is filtering outside air that enters the compressor system
b. Main motor
The function is driving Compressor via V-belt
c. V-belt
The function is distributing motor rotation to the compressor
d. Screw compressor
The function is increasing air pressure with the compression method
e. Oil filter
The function is filtering oil from dirt

3 RESEARCH METHODOLOGY

To predict a failure, qualitative and quantitative methods can be used. Qualitative method is a failure prediction method by collecting information from various informants, which later we can consider as a damage analysis. While the quantitative method is a statistical failure prediction of a system by utilizing. Various types of data distribution. The following are the steps used to analyze the failure of the screw compressor unit

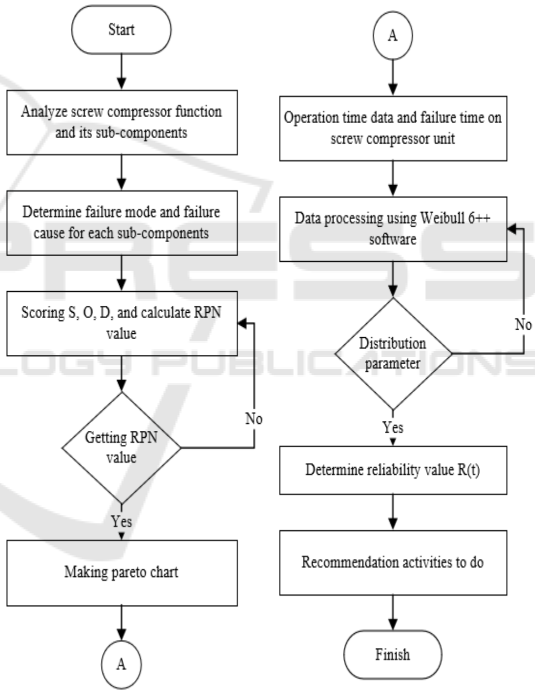

Figure 2. Research methodology

3.1 Qualitative Method

3.1.1 Failure Mode and Effect Analysis Method (FMEA)

FMEA is a methodology used to analyze and find all potential failures that occur in a system and find the effects of failures which occur on the system and how to improve or minimize failures or their effects on the system (improvement and minimalism is conducted based on a ranking of the severity and probability of failure). To analyze the potential failure system using the FMEA method, it requires 3 data, namely severity, assurance, and detection. Data severity, occurrence, and detection are obtained from various types of literature, which state the level of failure cause, the impact, and the instrument capability to read the potential failure.

Table 1: Screw compressor component and failure effect

Component	Function	Failure	Effect
Intake Filter	Filtering outside air that enters the compressor system	The accumulation of dust/dirt on the air filter so that there is clogging in the inlet	Airflow decreases so the risk of plugging on the tube and hopper in the ash handling system
Main motor	Driving Compressor via V-belt	Motor RPM decreases, Motor overheats, Low current supply	Decreasing air capacity interferes motor work
V-belt	Distributing motor rotation to the compressor	V-belt breaking	The motor cannot transmit rotation to the compressor
Screw compressor	Increasing air pressure with the compression method	the screw is worn and jammed	Air pressure decreases
Oil filter	Filtering oil from dirt	Clogged up dirt	Cooling oil circulation is disrupted

3.1.2 Logic Tree Analysis (LTA) Method

The compilation of Logic Tree Analysis (LTA) has the purpose of giving priority to each damage mode, showing the type of hazard category, and recommending steps that must be taken if a failure occurs. There are four important things in critical analysis as follows:

1) Evident, whether the operator knows that under normal conditions, there has been a disturbance in the system?
2) Safety, whether this failure mode causes safety problems?
3) The outage, whether this failure mode causes the whole or part of the machine stops?
4) The category is categorization obtained after answering the questions. In this section, the components are divided into four categories, namely:
   - Category A (Safety problem) if the failure mode has safety consequences for personnel and the environment.
   - Category B (Outage problem) if failure mode has consequences for plant operations (affecting the quantity or quality of output) that can cause significant economic losses.
   - Category C (Economic problem), if the failure mode does not have an impact on safety or operational plant and only causes relatively small economic losses for repairs.
   - Category D (Hidden failure) if the failure mode is classified as a hidden failure, which is then classified into D / A categories, D / B categories, and D / C categories.

The following is the LTA analysis obtained in this study, where the information is broken down into each type of damage in the screw compressor

Table 2 LTA analysis

Component	Damage	E	S	O
Intake Filter	The filter element is clogged with dust/dirt,	No	No	No
	Broken / torn filter element	No	No	No
Main motor	The motor RPM is decreasing	Yes	No	Yes
	Motor overheat	Yes	No	Yes
	Supply current is low	Yes	No	Yes
V-belt	V belt slip	No	No	Yes
	V belt is broken	No	No	Yes
	V belt is dirty	No	No	No
	Screw broke	No	No	No

Screw compressor	Screw stuck	No	No	Yes
Oil filter	Oil filter t clogged up	Yes	No	Yes
	Oil filter leak out	No	No	Yes

Information: E (Evident), S (Safety), and O (Outage)

3.2 Quantitative Method

The quantitative analysis method is a failure risk analysis method that uses a numerical approach to show the impact of damage to the tool. The data used determines TTF (time to failure) and TTR (time to repair) value than the Screw compressor operation. Then the data is processed using Weibull 6 ++ software, which serves to determine the suitable distribution used to determine the reliability function. From the data processing carried out, the results are as follows:

Table 3 Quantitative Methods result

Component	Distribution	Constant
Intake Filter	Lognormal	μ = 6,6553 σ = 0,1467
Main motor	Weibull	λ = 1.54275 γ = 0.9736 β = 5.1736 η =10757
V-belt	Lognormal	μ = 8,4586 σ = 0,6823
Screw compressor	Weibull	λ = 2.4735 γ = 1 β = 3,716 η =10813
Oil filter	Lognormal	μ = 6,6553 σ = 0,1467

Information :
t : failure time μ : mean
ϕ: normal distribution data
σ : deviation standart

Distribusi Weibull
Reliability function :

$$R(t)=e[-(t-\gamma\theta)\beta]$$

Information :
t : failure time
λ : lambda Weibull parameter
γ : gamma Weibull parameter
β : betha Weibull parameter
θ : tetha Weibull parameter

4 RESULT AND DISCUSSION

4.1 Analysis Results of Failure Mode and Effect Analysis (FMEA)

FMEA analysis is used to analyze all potential failures that occur in each component, to arrange the system, and determine the priority of damage in equipment. FMEA analysis is in the form of a risk priority number (RPN) value obtained from the multiplication between the value of severity, occurrence, and detection. The severity, occurrence, and detection values are obtained from the value scorers from value 1 to value 10. Severity has value 1 if the failure does not cause any effect, while value 10 if a dangerous condition occurs without warning after a failure occurs. The occurrence has value 1 if there is almost no failure in a component, while it is worth 10 if a component often fails. Detection has value 1 if preventive maintenance will always detect the potential cause of failure and failure mode while having value 10 if preventive maintenance is unable to detect potential causes of failure and failure mode.

In this study, there are 10 respondents, where each respondent was an expert in the field of screw compressor. Each respondent will assess the FMEA table according to the scale of the severity value, assurance, and detection that is in accordance with the facts in the field. After obtaining severity, assurance, and detection values, the value of the risk priority number (RPN) is calculated, which is a multiplication of the severity, occurrence, and detection values. To easily determine which component is the priority of improvement, a Pareto chart is made.

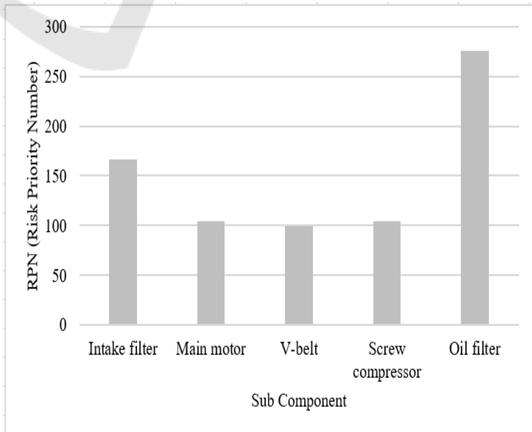

Figure 3. Pareto chart

From figure 3, it can be seen that by using the FMEA method, the RPN value is obtained from the highest one, such as oil filter, intake filter, v-belt, main motor, and screw. The higher the value of RPN, the component has a higher priority to be replaced when damage occurs because it has a very high urgency. This indicates that the oil filter and intake filter have low reliability and a high rate of damage so that it requires periodic checks. The low level of reliability and the high rate of damage to the oil filter can be caused by several things, including the low quality of oil filter, the work of the oil filter, which is too heavy because the oil is too dirty and inconvenient repair techniques.

4.2 Logic Tree Analysis (LTA) Analysis Results

LTA analysis shows the types of hazard categories and recommends steps that must be taken when a failure occurs. Table 4 below shows the hazard level category for each screw compressor.

Table 4 LTA Methode Analyze

Component	Damage	Category
Intake Filter	The filter element is clogged with dust/dirt,	C
	Broken/torn filter element	D
Main motor	The motor RPM is decreasing	B
	Motor overheat	B
	Supply current is low	C
V-belt	V belt slip	C
	V belt is broken	B
	V belt is dirty	D
	Screw broke	C
Screw compressor	Screw stuck	B
Oil filter	Oil filter t clogged up	C
	Oil filter leak out	C

Based on table 4, each component has a different category of damage. Oil filters and intake filters belong to the C / D category because the damage does not have an impact on the safety and operational unit, even the damage that occurs can be hidden accident. While the damage in the v-belt is in the B / C category. Failure will be classified as category B if the belt breaks because it will affect the screw compressor operating system. While the damage will be classified as category C if the damage is only minor damage such as v-belt dirty and slippage. Whereas damage to motorbikes and screws is included in the B/ C category. Damage is included in category B if there is a decrease in RPM and overheats on a motorbike, or when the screw jams. Category C occurs when the supply of electric current is reduced at the main motor, or when there is wear screw so that it can cause a decrease in screw compressor performance

4.3 Reliability Function Analysis

The reliability function analysis is used to determine the reliability value based on quantitative operational time. Quantitative data is obtained from operational data of the tool, which is then processed using Weibull 6 ++ software, which displays the value of R (t) using each distribution. Figure 4 below shows a graph of the reliability function R (t) of each component.

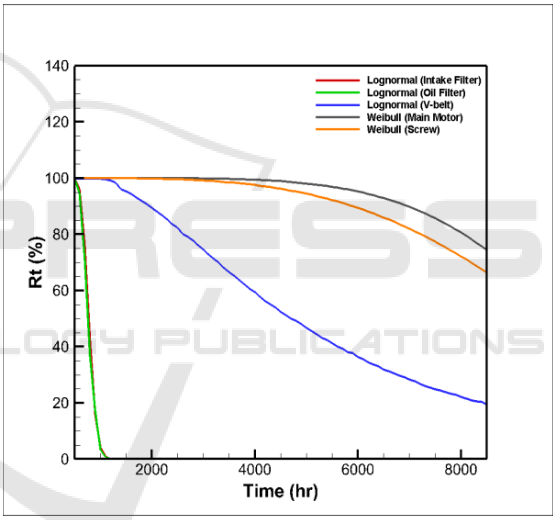

Figure 4. Graph of the reliability function R (t) of each component

From this graph, it can be seen that the components of the intake filter, oil filter, and V-belt have the same Lognormal failure distribution equation, while Main Motor and Screw have the Weibull failure distribution equation. To reach Rt = 0%, the intake filter and oil filter need 1500 hours. The V-belt component, at variable (t) maximum (8500 hours), reaches Rt = 19.49%. While the Main Motor and Screw Components, the variable (t) maximum (8500 hours), each reach Rt = 74.41% and Rt = 66.45%.

4.4 Recommendation Maintenance

After analyzing the damage to the screw compressor subcomponent, the next step is the recommendation for proper maintenance and repair. Appropriate improvement recommendations for each component are as follows:

a. Intake Filter

From the results of both qualitative and quantitative analyses, the intake filter shows a low level of endurance. So that the right maintenance schedule is needed to be more efficient. The recommended treatment schedule is 25-27 days. From the calculation results, the reliability obtained when 25-27 days is 77.04% - 89.07%. The recommended types of maintenance are preventive maintenance and corrective maintenance.

- Preventive maintenance, what can be done is cleaning the intake filter using compressed air to reduce the accumulation of dust attached to the intake filter element.
- Corrective maintenance, what can be done, is to replace the intake filter periodically.

b. Oil Filter

From the results of qualitative and quantitative analysis, the level of reliability in the oil filter is the lowest compared to other sub-components. The recommended treatment schedule is 28-29 days. From the calculation results, the reliability obtained when 28-29 days is 79.95% -72.57%. The recommended types of maintenance are preventive maintenance and corrective maintenance.

- Preventive maintenance, what can be done is to clean the area around the oil filter to find out whether there is oil leakage or not.
- Corrective maintenance, what can be done, is to replace the oil filter periodically.

c. V-belt

From the results of qualitative and quantitative analysis, the reliability value of 99.7% when t = 30 days. The recommended treatment schedule is 105 - 125 days. From the calculation results, the reliability obtained when 105 - 125 days is 82.38% - 74.54%. The type of maintenance recommended is preventive maintenance.

- Preventive maintenance, what can be done is to clean the v-belt from dirt or dust, which also checks the visual condition.

d. Main Motor

From the results of qualitative and quantitative analysis, the reliability value of 99.92% when t = 30 Days. The recommended treatment schedule is 334 - 355 days. From the calculation results, the reliability obtained when 334-355 days is 80.57% - 74.41%. The type of maintenance recommended is preventive maintenance.

- Preventive maintenance, what can be done is to do the cleaning on the motorbike to remove dust or dirt on the body of the main motorbike and also check the condition of the motorbike visually.

e. Screw

From the results of qualitative and quantitative analysis, the reliability value is 99.99% when t = 30 days. The recommended treatment schedule is 292 - 313 days. From the calculation results, the reliability obtained when 292 - 313 days is 80.57% - 74.41%. The recommended types of maintenance are preventive maintenance, predictive maintenance, and corrective maintenance.

- Preventive maintenance, what can be done is to change the intake filter regularly because damage to the intake filter can cause damage to the screw. In addition, oil filter replacement can also extend the lifetime of the screw.

5 CONCLUSION

Based on failure risk analysis discussion in screw compressors using qualitative and quantitative methods, the following conclusions are obtained:

1. By using qualitative FMEA analysis, the repair priority order in a screw compressor ash handling system based on the RPN rating is the oil filter, intake filter, v-belt, main motor, and screw. This means that if there is damage to the screw compressor, the component that must be corrected first is the oil filter component.
2. By using qualitative LTA analysis, the damage categories for each sub-component are as follows :

a. Oil filters are C category
b. The intake filter is C/D category
c. V-belts are B/C/D category
d. The main motor is B/C category
e. The screw is B/C category

3. Recommended treatment time to do is as follows:

a. Intake Filter: 25 - 27 days
b. Oil Filter: 28 - 29 days
c. V-belt : 105 - 125 days
d. Main motor: 330 - 335 days
Screw : 292 - 313 days

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