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Designing The Estimation of The Need for Spare Parts and Inventory Policy on The D32 CP8 Compressor Machine

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Abstrak

Berdasarkan data kerusakan yang dimiliki PT XYZ, mesin kompresor yang memiliki riwayat kerusakan tinggi adalah Mesin Kompresor D32 CP8. Komponen kritis dari Kompresor D32 CP 8 ditentukan menggunakan matriks risiko. Komponen kritis yang dipilih dari Mesin Kompresor D32 CP8 adalah Motor Sekrup, Pendingin Udara Refrigeran, dan Pendingin Oli Bantalan Silinder. Penelitian ini menggunakan metode *Reliability Centered Spares* (RCS), *Min-Max Stock*, dan *Reorder Point* (ROP). Hasil pendataan dan pengolahan yang dilakukan didapatkan kebutuhan komponen kritis dalam 1 tahun ke depan berdasarkan data komponen kritis MTTF. Dari perhitungan tersebut diperoleh nilai kebutuhan suku cadang Motor Sekrup, Pendingin Udara Refrigeran, dan Pendingin Oli Bantalan Silinder dalam setahun adalah 8 komponen. *Stock* minimum *Screw* Motor adalah 3 komponen, stock maksimum 8 komponen, *ReOrder* Point point bila 4 komponen. Stok minimum pendingin udara pendingin 4 komponen, stok maksimum 7 komponen, titik ReOrder Point ketika 3 komponen. Stok minimum Cylindrical Bearing Oil Cooler adalah 2 komponen, stok maksimum 6 komponen, dan titik ReOrder Point saat 2 komponen.

Keywords:
compressor;
maintenance;
risk matrix;
RCS;
min-max stock.

Abstract

Based on damage data owned by PT XYZ, the compressor engine that has a history of high damage is the D32 CP8 Compressor Engine. Critical components of the D32 CP 8 Compressor are determined using a risk matrix. The critical components selected from the D32 CP8 Compressor Engine are Screw Motor, Refrigerant Air Cooler, and Cylinder Bearing Oil Cooler. This study uses the Reliability Centered Spares (RCS), Min-Max Stock, and Reorder Point (ROP) methods. The data collection and processing results obtained the need for critical components in the next 1 year based on the MTTF critical component data. These calculations show that the value of the required spare parts for the Motor Screw, Refrigerant Air Conditioner, and Cylinder Bearing Oil Cooler in a year is 8 components. The minimum Stock of the Screw Motor is 3 components, the maximum stock is 8 components, ReOrder Point point is 4 components. The minimum stock of 4 component air coolers, maximum stock of 7 components, ReOrder Point when 3 components. The minimum stock of a Cylindrical Bearing Oil Cooler is 2 components, the maximum stock is 6 components, and the ReOrder Point is when there are 2 components.

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1. Introduction

Angelina, Atmaji, and Santosa in their study of RCS presented an analysis of spare parts and inventory of steel tape and brass inserts as key components in research for Rovema packaging machines. Applying the Reliability Centered Spares (RCS) method to calculate the optimal component stock needs using Poisson Proces and Min-Max inventory analysis [1]. The results showed that steel tape and brass inserts should be stored in technical warehouses for a certain amount in the next period to minimize downtime due to the unavailability of spare parts [1].

Inventory management policy is very important in a company. Lacking a good inventory control system, the company cannot carry out production smoothly, and it is also difficult to meet customer needs. Inventory is the part of the company's expenses that absorb the most costs. Causes of Excess Inventory Storage costs are high, but there may be a risk of not being met if the stock shortage needs clients. Spare parts inventory is one of the important aspects that support the overall inventory systems in the manufacturing process.

XYZ company, a manufacturing company engaged in building materials, also faces obstacles related to the supply of spare parts. In the production section, there are several machines used in the production process, one of which is a compressor. But in reality, machine reliability may degrade over time, leading to machine downtime. Based on the compressor engine inspection data owned by XYZ company, the overheating frequency for each compressor engine can be known.

Based on Figure 1, it is known that the highest overheating frequency occurs in the D32 CP 8 compressor engine, which is 87 times. Based on the data above, the D32 CP 8 compressor engine is the engine that has the highest overheating rate from January 2021 – December 2021, which is 87 times. Compressor D32 CP8 is a compressor machine

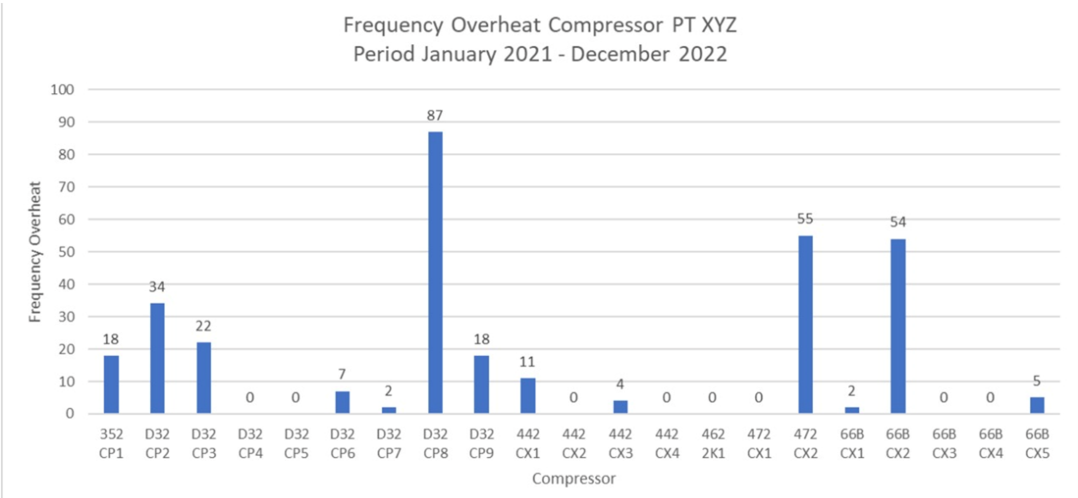

Figure 1. Compressor Overheat Frequency

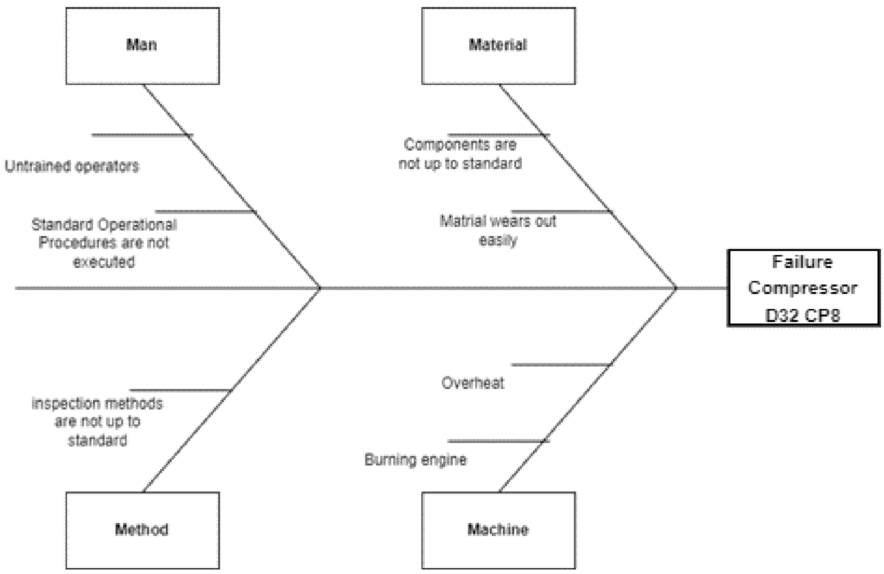

Figure 2. Fishbone Diagram of the Problem

that is crucial for the production process. Compressor D32 CP 8 is a compressor that functions to supply pressure to one of the main production machines so that the main production machine can work according to its standards. If the pressure required on the main production machine cannot be met, the production process will automatically stop.

The results of an interview with the Mechanical Maintenance Manager, several factors cause the high frequency of overheating in the D32 CP8 Compressor. Such factors can be deciphered using the fishbone diagram in figure 2.

Based on Figure 2, it can be seen that several factors are suspected to be the cause of the damage suffered by the D32 CP 8 Compressor. From the point of the man factor, the operator is poorly trained in handling the D32 CP 8 Compressor both in maintaining and conducting inspections, the available SOPs are not run by the operator. From the point on the machine factor, the D32 CP 8 Compressor engine experiences breakdown maintenance because the engine burns, this is because the compressor engine often overheats. From the point of the method factor, the inspection method is not following company standards. From this point on the material, the factor is that the components are not up to standard and the material that the components are easy to wear out.

2. Research Methods

2.1 Flowchart Research Methods

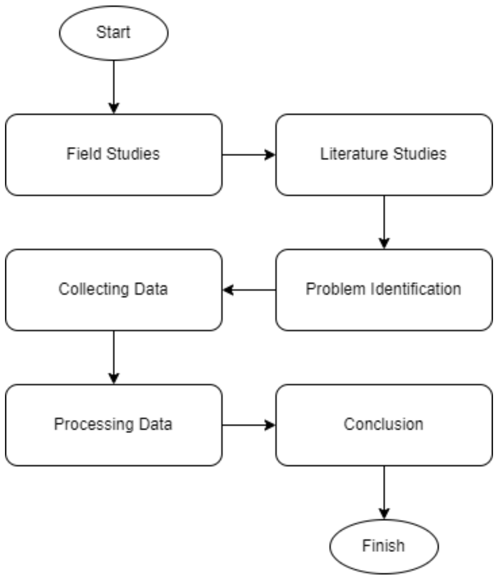

Figure 3. Flowchart Research

Field Studies are the initial stage in the implementation of this research. Literature and literature studies are conducted to help the author understand the concepts and methods used to solve the problems contained in field. Problem Identification is the next stage after the results are obtained in field studies. Problem identification is a very important step in this study because it will be the beginning of the problem-solving system. After the problem identification stage is carried out, the determination of the solution and the objectives of the final project will be carried out in the data collection stage that will be used in the research. After the data needed for research has been collected, the next stage is the data processing data. At this stage, the existing data will be calculated according to the theory already studied in the literature study. Analysis of the results of data collection and processing that has been carried out to determine the results of inventory policies that are in accordance with data calculations. Conclusion is the submission of the conclusions in this study as well as the submission of suggestions for the company.

2.2 Maintenance

This section explains the meaning of maintenance which is used as a basis in this study. Maintenance is an act of maintenance and repair of an object. In the industrial world, maintenance is meant the maintenance of factory components or machines and updating the performance of components or machines so that the service life of the component or machine is optimal when the engine is damaged and unfit for use[2]. Maintenance is divided into two, namely: preventive maintenance and corrective maintenance [3].

Preventive Maintenance is maintenance that is carried out on a scheduled basis. Generally periodically, where many activities such as inspection and repair, replacement, cleaning, lubrication, and adjustment and equalization are carried out, preventive maintenance is machine maintenance activities carried out to prevent damage and find conditions that can cause production facilities or machines to be damaged at the time of production [4].

Corrective maintenance is maintenance that is carried out after an error occurs, it aims to restore the equipment to a state where the equipment can perform the necessary functions directly or suspended, Corrective Maintenance is a remedial action that does not have a routine schedule for repairing equipment or components in ready-made condition [5], [6]. Corrective Maintenance usually cannot be planned because this activity is carried out with damaged components and then repaired so that it can run optimally again [3].

2.3 Maintainability

Maintainability is the opportunity for a damaged system or component to be restored to full working condition within a predetermined time and with certain maintenance procedures. Maintainability also relates to the duration of maintenance or how long it takes to complete a maintenance action (ease and speed). The characteristics of the maintenance capability are usually determined by the design of the equipment, which then establishes the maintenance procedure of the machine and determines the length of the repair time.

2.4 Reliability Centered Spares

Reliability Centered Spares is an approach to determining the level of spare parts inventory based on through-life costing and equipment needs and machine maintenance operations in support of inventory. Reliability Centered Spares (RCS) is one of the parts management methods by considering aspects such as the maintenance needs of the machine needed, what happens if the tribe spare parts are not available, anticipate the need for spare parts, the number of spare parts stock storage needed, and what machine maintenance requirements should be carried out [7].

2.5 System Breakdown Structure

System Breakdown Structure is the first step in identifying the components of a system by conducting a more detailed analysis of the system [8]. The main purpose of this system breakdown structure is to analyze all components contained in the system based on functions so that it can help to determine critical components [9].

2.6 Management Parts

Spare parts are components that must be available to maintain the ability of machine equipment to always be in good condition and can operate properly. In maintenance engineering, the cost of parts is a large expense, and spare parts are very important for the availability of equipment, spare parts are a significant resource in equipment maintenance [10].

Parts Classification is a grouping activity on parts that is useful for deciding which management parts strategy to apply to these components. Spare parts are divided into 2 types, namely repairable components, and non-repairable components, therefore spare parts management is needed (spare parts management) and controlling the availability of spare parts [11].

Components are considered non-repairable when they are difficult to repair and the cost to repair is much more expensive than buying new components. In the calculation of the number of non-repairable parts component needs, the number of failures that occur is equal to the number of parts needed. The number of parts component needs is the minimum value of (n) with the following calculation:

$$\lambda t = \frac{1}{MTTF} t = \frac{A.N.M.T}{MTTF} \tag{1}$$

Description:

λt : Mean value (the amount of damage that occurs at a time)
MTTF : Mean Time Between Failure
A : Number of installed components
N : Number of machines
M : Machine operational time
Q : Usage period

When reconditioning the machine and involving the replacement of components it is necessary to hold the spare parts components, so the calculation is:

$$P \leq \sum_{x=0}^{n-1} \frac{\lambda t^x e^{-\lambda t}}{x!} = e^{-\lambda t}[1 + \lambda t + \cdots + \frac{(\lambda t)^{n-1}}{(n-1)}] \tag{2}$$

Information:
P: Level of trust

2.7 Risk Matrix

The Risk Matrix is a mechanism to clarify process risks that are usually identified through one or more objectives. The following are the advantages of using a risk matrix:

1. Very functional When used in field practice workers can avoid all kinds of risks that occur.
2. Make a standard tool for establishing the relationship between probability and consequence of risk.
3. Disables the acceptance of unacceptable risks and allows for operational decision-making.

Characteristics of the risk matrix, namely:

1. Simple and easy to understand
2. Have a clear orientation to its application
3. Have a clear sense of the consequences that have a range of values in each existing consequence
4. Provides very clear guidance on what actions are needed to deal with an unbearable level of risk.

2.8 Mean Time to Failure (MTTF)

Mean Time to Failure (MTTF) is the average time between the failure of a machine or system when it starts operating until it experiences a failure [12]–[14]. When the rate of damage to components/systems depends on their service life, the statistical distribution used is the Normal and *Weibull* distributions.

1. Normal Distribution

   The parameters used in the normal distribution are *the mean* (μ) and the standard deviation (σ). The reliability functions on this distribution are:

$$\text{MTTF} = \mu \tag{3}$$

2. Exponential Distribution

   The parameter used on the Exponential distribution is lambda (λ). Has a constant value against time. The average time between damages to this distribution is:

$$\text{MTTF} = \int R(t)dt = \frac{1}{\lambda} = \mu \tag{4}$$

3. Weibull distribution

   The parameters used in the *Weibull* distribution are the service life parameter (α), the form parameter (β), and the location parameter (γ). The average time between damages in this distribution is:

$$\text{MTTF} = \alpha.\Gamma(1 + \frac{1}{\beta}) \tag{5}$$

With:
$\Gamma(1 + \frac{1}{\beta})$: Table of gamma functions Γ(x)

2.9 *Min-Max Stock*

Min-Max stock is a method for determining the minimum amount of stock and maximum stock of spare parts [15]. The purpose of implementing *min-max* stock is so that the warehouse part knows the inventory of spare parts needed to meet the production capacity and maximum stock of spare parts in the warehouse [16]. The following is how to calculate the *min-max stock* method.

$$\text{Safety Stock} = (\text{Maximum Usage-T}) \times C \tag{6}$$
$$\text{Min Stock} = (T\times C)+S$$
$$\text{Max Stock} = 2\times(T\times C)$$

Description:

Q: Average usage per given period (Units)
C: Lead time spare parts (Month)
S: Safety stock (Unit)

ReOrder Point is the point or limit of inventory to be reordered [17]. The calculation of *ReOrder Point* is determined by the length of *lead time*, average usage, and *safety stock* [18]. Here is the equation in the *ReOrder Point calculation.*

$$ROP = (AU \times LT) + SS \quad (7)$$

Description:

ROP : ReOrder Point
AU : Average usage per period
LT : Lead time (Month)
SS : Safety stock (Unit)

3. Results and Discussion

Compressors are designed to work automatically 24 hours a day, 7 days a week to produce compressed air used to drive production machines that require the availability of compressed air continuously to ensure the quality of the machine [19]. The most commonly used type of compressor is a screw compressor. Screw compressors are high air flow compressors compared to other types of air compressors and can operate non-stop 24 hours a day [20]. In this study, the compressor used as an object was presented in table 1.

Table 3. Data Compressor

Compressor D32 CP8	
Maker	Mannasman
Type	Marathon 250/132 KW
Volume	25.3 m
Pressure	10 Bars
Speed	1500 Rpm

Table 4. System Breakdown Structure

No.	Component
1.	Main Bearing
2.	V-Belt
3.	Screw Motor
4.	Air Filter
5.	Oil Filter
6.	Oil Separator
7.	Refrigerant Air Cooler
8.	Cylindrical Bearing Oil Cooler

3.1 System Breakdown Structure

System Breakdown Structure is the first step in identifying the components of a system by conducting a more detailed analysis of the system. Table 2 shows the system breakdown structure of the D32 CP8 Compressor engine.

3.3 Machine Downtime

Downtime is defined as the time a system component cannot be used (not in good condition), thus making system functions not run. Another definition of downtime is the accumulation of time that occurs in machines/equipment when they cannot operate due to other activities that must

Table 1. Machine Downtime

No.	Component	Frequency of Damage	Amount of Downtime (Minutes)	Downtime (%)	Cumulative (%)
1.	Screw Motor	12	4440	32,32%	32,32%
2.	Refrigerant Air Cooler	13	5202	37,87%	70,19%
3.	Cylindrical Bearing Oil Cooler	13	3775	27,48%	97,67%
4.	Oil Separator	1	320	2,33%	100%
	Sum	39	13737	100%	

Table 2. Risk Matrix

Likelihood		Severity				
		1	2	3	4	5
		Insignificant	Minor	Moderate	Major	Catastrophic
5	Almost Certain					
4	Likely					
3	Possible			Screw Motor, Refrigerant Air Cooler, Cylindrical Bearing Oil Cooler		
2	Unlikely		Bearing V-Belt, Oil Filter, Oil Separator	Air Filter		
1	Rare					

Table 5. Classification of Critical Components

Component	Classification
Screw Motor	Non-repairable
Refrigerant Air Cooler	Non-repairable
Cylindrical Bearing Oil Cooler	Non-repairable

Table 6. TTF Distribution Test

Component	Distribution	AD value	P-Value	Selected Distributions
Screw Motor	Normal	0,399	0,301	Normal
	Exponential	0,767	0,203	
	Weibull	0,499	0,199	
Refrigerant Air Cooler	Normal	0,133	0,971	Normal
	Exponential	1,790	0,012	
	Weibull	0,140	>0,250	
Cylindrical Bearing Oil Cooler	Normal	0,326	0,470	Normal
	Exponential	1,648	0,018	
	Weibull	0,326	≥0,250	

be carried out. One of the causes of downtime is the disruption of the production process. Table 4 presents compressor engine downtime data for the period 2019-2021.

3.2 Risk Matrix

Critical components are determined based on the results of *risk matrix calculations.* the following is a table of *likelihood* and *severity risk matrix* scores based on questionnaires filled out directly by employees. Risk Matrix is applied at the beginning of data processing to determine the critical components of the D32 CP 8 compressor machine. The filling of the Risk Matrix is carried out directly by the person in charge of the company's compressor. Table 4. Shows the risk matrix for the D32 CP8 Compressor. There are three critical components of the D32 CP8 Compressor, namely *the Screw Motor, Refrigerant Air Cooler, and Cylindrical Bearing Oil Cooler*.

3.4 Critical Component Classification

Critical components are clarified to be non-repairable or repairable. If critical components belong to the category of non-repairable components, then if they are damaged, they must be replaced with new components. If critical components include repairable components, then if they experience damage, repairs can be made. This classification is carried out because the calculation of the number of components needs a different calculation method. Table 5 shows the classification of each predetermined critical component.

3.6 Determination of Time to Failure Distribution

The Distribution Test was performed to determine the distribution representing time to failure (TTF) using the Anderson Darling (AD) test. The test is carried out on three distributions namely the Normal distribution, the Exponential distribution, and the Weibull distribution. The AD value will determine that the distribution represents the spread of data by looking at its AD value. The smallest AD value will determine the distribution that represents the spread of data. The P-Value value is used as a parameter for the acceptance or rejection of a hypothesis provided that H0 is rejected on the P-Value < α. This data uses a significant level (α) of 0.05 (95%). In determining the distribution for each critical component, it is assisted by using Minitab software. Table 6 shows the results of the distribution test using Minitab software [21].

Based on Table 6, can be seen the selected distribution for each spare part. Screw motor is normally distributed, Refrigerant Air Cooler is normally distributed, cylindrical bearing Oil Cooler is normally distributed

3.5 Determination of Time to Failure Parameters

Parameterization on the distribution of critical component TTF data using AvSim+ 9.0 software. The obtained parameters will be used to calculate the Mean Time to Failure (MTTF) value. Table 7 describes the parameters obtained from the distribution of TTF data using AvSim+ 9.0 software.

3.7 Determination of the Value of Mean Time to

The determination of the value of MTTF is carried out based on the type of distribution of each critical component with a formula corresponding to the selected distribution. Table 8 shows the calculation of MTTF of critical components.

The calculation of the number of *spare part*s needs is carried out to meet the needs of spare parts in the next 1 year using the *Poisson Process* method. The calculation of the number of parts is carried out based on the type of repair of components. Screw *Motor Components*, *Refrigerant Air* Coolers, and *Cylindrical Bearing Oil* Coolers are components that are included as *non-repairable* components. Then in the event of damage, the component must be replaced. Some *of* the variables used to calculate the number of *non-repairable* parts needed are *the Mean Time to Failure* (MTTF) value, the number of components, the level of confidence, the number of machines used, the period of use, and the operating time. The level of trust in this study is 95% obtained based on referrals from the

Table 6. TTF Parameters

Component	Distribution	Parameters	
Screw Motor	Normal	μ	2058,42
		σ	1909,69
		ρ	0.974853
		ε	0.0590031
		B10	0
		P0	0%
Refrigerant Air Cooler	Normal	μ	1899,85
		σ	1108,57
		ρ	0.991782
		ε	0.0306051
		B10	479,158
		P0	0%
Cylindrical Bearing Oil Cooler	Normal	μ	1967.61
		σ	1252.38
		ρ	0.981391
		ε	0.0430363
		B10	362.616
		P0	0%

Table 7. Mean Time to Failure

Component	Distribution	Parameters		1/(β+1)	Gamma Table	MTTF
Screw Motor	Normal	μ	2058,42	-	-	2058,42
		σ	1909,69			
Refrigerant Air Cooler	Normal	μ	1899,85	-	-	1899,85
		σ	1108,57			
Cylindrical Bearing Oil Cooler	Normal	μ	1967.61	-	-	1967.61
		σ	1252.38			

Table 8. Spare Parts Needs

Component	Spare Parts Needs
Screw Motor	8
Refrigerant Air Cooler	8
Cylindrical Bearing Oil Cooler	8

Table 9. Usage Data and Leadtime Spare Parts

Component	Year			Lead Time (days)
	2019	2020	2021	
Screw Motor	3	5	4	45
Refrigerant Air Cooler	6	4	3	30
Cylindrical Bearing Oil Cooler	5	5	3	30

Table 11. Spare Parts Inventory Policy

No.	Component Name	Calculation of Spare Parts Needs	Safety Stock	Minimum Stock	Maximum Stock	ReOrder Point
1	*Screw Motor*	8	2	3	8	4
2	*Refrigerant Air Cooler*	8	2	4	7	3
3	*Cylindrical Bearing Oil Cooler*	8	1	2	6	2

need for critical parts in the next 1 year.

Based on Table 9, it can be known that to meet 95% of the availability needs of critical components in the next 1 year, the company needs 8 Screw Motor components, 8 Refrigerant Air Cooler components, and 8 Cylindrical Bearing Oil Cooler components.

3.8 Inventory Policy Determination

The determination of inventory policy is carried out to determine the minimum and maximum inventory quantities of spare parts so that they are always available and there is no buildup in the warehouse. Inventory policy determination is carried out using the Min-Max Stock method, and ReOrder Point. Min-Max Stock is used to determining the minimum and maximum inventory quantities. Table 10 shows data on the use of critical components and lead time for 2019-2022.

Based on Table 11, it can be seen the minimum number of stocks, maximum stocks, and ReOrder Points of each component. The minimum stock on the Screw Motor is 3 components, a refrigerant air cooler is 4 components, Cylindrical Bearing Oil Cooler is 2 components. The maximum stock on the Screw Motor is 8 components, a refrigerant air cooler is 7 components, Cylindrical Bearing Oil Cooler is 6 components. The ReOrder Point on the Screw Motor is 4 components, the Refrigerant Air Cooler is 3 components, and the Cylindrical Bearing Oil Cooler is 2 components.

4. Conclusion

From the calculation process that has been carried out, it can be concluded that based on calculations using the Risk Matrix, there are three critical components of the D32 CP8 Compressor Machine, namely the Screw Motor, Refrigerant Air Cooler, and Cylindrical Bearing Oil Cooler. Based on the results of the calculation of the number of spare parts needed for the next 1 year using the Reliability Centered Spares method, namely the Poisson Process, 8 Screw Motor components were obtained. components, Refrigerant Air Cooler as many as 8 components, Cylindrical Bearing Oil Cooler as many as 8 components. Based on the results of the inventory policy calculation using the Min-Max Stock method, and ReOrder Point, the minimum value of the component stock, maximum component stock, and ReOrder Point for each component are obtained critically. Min-max stock for Screw Motor components is 3 components and 8 components, Refrigerant Air Cooler is 4 components and 7 components, and Cylindrical Bearing Oil Cooler is 2 components and 6 Components. The ReOrder point for each component is 4 Components Screw Motor, 3 Components Refrigerant Air Cooler, 2 Components Cylindrical Bearing Oil Cooler.

References

[1] C. F. Angelina, F. T. D. Atmaji, and B. Santosa, “Spare Part Requirement and Inventory Policy for Rovema’s 1 Machine using Reliability Centered Spare (RCS) and Min-Max Stock Methods,” in *IOP Conference Series: Materials Science and Engineering*, 2020, vol. 722, no. 1, p. 12017.

[2] Q. Lv, X. Yu, H. Ma, J. Ye, W. Wu, and X. Wang, “Applications of machine learning to reciprocating compressor fault diagnosis: A review,” *Processes*, vol. 9, no. 6. 2021, doi: 10.3390/pr9060909.

[3] G. Qi, Z. Zhu, K. Erqinhu, Y. Chen, Y. Chai, and J. Sun, “Fault-diagnosis for reciprocating compressors using big data and machine learning,” *Simul. Model. Pract. Theory*, vol. 80, 2018, doi: 10.1016/j.simpat.2017.10.005.

[4] S. M. Hipple, H. Bonilla-Alvarado, P. Pezzini, L. Shadle, and K. M. Bryden, “Using machine learning tools to predict compressor Stall,” *J. Energy Resour. Technol. Trans. ASME*, vol. 142, no. 7, 2020, doi: 10.1115/1.4046458.

[5] S. J. m. Tahir and E. AKIN, “Predictive Maintenance of Compressor Using ThingSpeak IoT Platform,” *Int. J. Sci. Res. Manag.*, vol. 9, no. 06, 2021, doi: 10.18535/ijsrm/v9i06.ec01.

[6] S. Qiu, X. Ming, M. Sallak, and J. Lu, “Joint optimization of production and condition-based maintenance scheduling for make-to-order manufacturing systems,” *Comput. Ind. Eng.*, vol. 162, 2021, doi: 10.1016/j.cie.2021.107753.

[7] V. Aulia, J. Alhilman, and S. Nurdinintya-Athari, “Proposed Maintenance Policy and Spare Part Management of Goss Universal Printing Machine with Reliability Centered Maintenance, Reliability Centered Spares, and Probabilistic Inventory Model,” in *Proceeding of 9th International Seminar on Industrial Engineering and Management*, 2016, pp. 81–86.

[8] F. B. B. Nasution and N. E. N. Bazin, “Creating model with system breakdown structure for system dynamics,” *Indones. J. Electr. Eng. Comput. Sci.*, vol. 6, no. 2, 2017, doi: 10.11591/ijeecs.v6.i2.pp447-456.

[9] O. A. Makinde, K. Mpofu, B. I. Ramatsetse, M. K. Adeyeri, and S. P. Ayodeji, “A maintenance system model for optimal reconfigurable vibrating screen management,” *J. Ind. Eng. Int.*, vol. 14, no. 3, 2018, doi: 10.1007/s40092-017-0241-7.

[10] I. Hussain, S. U. Rahman, A. Zaheer, and S. Saleem, “Integrating factors influencing consumers’ halal products purchase: Application of theory of reasoned action,” *J. Int. Food Agribus. Mark.*, vol. 28, no. 1, 2016, doi: 10.1080/08974438.2015.1006973.

[11] M. Rucco, F. Giannini, K. Lupinetti, and M. Monti, “A methodology for part classification with supervised machine learning,” *Artif. Intell. Eng. Des. Anal. Manuf. AIEDAM*, vol. 33, no. 1, 2019, doi: 10.1017/S0890060418000197.

[12] K. K. Sudheesh, G. Asha, and K. M. Jagathnath Krishna, “On the mean time to failure of an age-replacement model in discrete time,” *Commun. Stat. - Theory Methods*, vol. 50, no. 11, 2021, doi: 10.1080/03610926.2019.1672742.

[13] N. Yunus, M. Othman, and Z. M. Hanapi, “Mean time to failure analysis in shuffle exchange systems,” *Int. J. Eng. Adv. Technol.*, vol. 9, no. 1, 2019, doi: 10.35940/ijeat.A2644.109119.

[14] R. Florin, A. G. Zadeh, P. Ghazizadeh, and S. Olariu, “Towards Approximating the Mean Time to Failure in Vehicular Clouds,” *IEEE Trans. Intell. Transp. Syst.*, vol. 19, no. 7, 2018, doi: 10.1109/TITS.2017.2710353.

[15] A. P. Kinanthi, D. Herlina, and F. A. Mahardika, “Analisis Pengendalian Persediaan Bahan Baku Menggunakan Metode Min-Max (Studi Kasus PT.Djitsoe Indonesia Tobacco),” *PERFORMA Media Ilm. Tek. Ind.*, vol. 15, no. 2, 2016.

[16] T. Iqbal, D. Aprizal, and M. Wali, “Aplikasi Manajemen Persediaan Barang Berbasis Economic Order Quantity (EOQ),” *J. JTIK (Jurnal Teknol. Inf. dan Komunikasi)*, vol. 1, no. 1, pp. 48–60, 2017.

[17] T. Lukmana and D. T. Yulianti, “Penerapan Metode EOQ dan ROP (Studi Kasus: PD. Baru),” *J. Tek. Inform. dan Sist. Inf.*, vol. 1, no. 3, 2015.

[18] G. G. Kencana, “Analisis Perencanaan dan Pengendalian Persediaan Obat Antibiotik di RSUD Cicalengka Tahun 2014,” *J. Adm. Rumah Sakit Indones.*, vol. 3, no. 1, 2018.

[19] A. D. Susanto and H. H. Azwir, “Perencanaan Perawatan Pada Unit Kompresor Tipe Screw Dengan Metode RCM di Industri Otomotif,” *J. Ilm. Tek. Ind.*, vol. 17, no. 1, 2018, doi: 10.23917/jiti.v17i1.5380.

[20] B. F. Zakaria, M. A. Murti, and A. S. Wibowo, “Sistem Pemantauan Kompresor Udara Berbasis Internet Of Things,” *eProceedings Eng.*, vol. 7, no. 1, 2020.

[21] Sugiyono, *metode penelitian kualntitaltif, kuallitaltif,daln R&D*. Jakarta: Alfabeta, 2017.