Implementation of Reliability Centered Maintenance Method for Pump on Fuel Distribution Companies

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***Abstract*—** The application of the reliability centered maintenance method or known as "RCM" in the effort to maintain and repair pumps carried out at fuel distribution companies is an action that focuses on pump reliability. Based on the ISO Saverity Rate 10816, there are 8 out of 32 fuel pump distribution companies in the 2021 period experiencing the Unsatisfactory category with a vibration value of more than 4.5 mm/s. Based on these conditions, it is necessary to apply the reliability centered maintenance method as an effort to improve pump maintenance management. The implementation of pump maintenance management in this RCM method focuses on determining the reliability value of the pump with an exponential reliability system, identifying the dominant value on which component of the pump has the highest damage frequency value. Besides that, the implementation of the RCM method on this pump also relies on the implementation of the root cause of the problem in order to get the main factor causing the pump failure which is then carried out by compiling a 5W + 1H table to identify corrective actions for the company's pump maintenance design. With the application of this RCM method, recommendations for maintenance should be obtained based on the damage that occurred to the company's pump.

***Keywords*—** Method, Failure, Dominan, Pump.

I. INTRODUCTION

Maintenance or known as the maintenance of an equipment is an effort that must be done in order to maintain an achievement of equipment performance that is close to the same as the initial or new condition (Setiawiyono, 2019). The fuel oil distribution company implements a pump vibration inspection system. Based on the identification of ISO 10816 - Vibration Severity as a guideline or standard for pump engine reliability by measuring the allowable vibration threshold limit on the pump with the vibration value parameter on the pump classification and its foundation, the results of the company's initial pump evaluation were obtained. The results of the evaluation identification obtained 8 out of 32 pumps included in the pump with the "Unsatisfactory" category, namely with a vibration value of 4.6-11.2 mm/s for the rigid foundation type, while the company's minimum standards are in satisfactory conditions, namely 1.9-4.5mm/s with the identity of the pumps including namely Pump: 7-PX_Blg, 8-PX_Blg, 10-FM_Byl, 11-PM_Sub, 15-PM_Sub, 16-PT_Sub, 6-PX_Grm, 5-PX_Grm. The results of this data processing are shown in figure 1 Condition of companies Pumps on 2021

Table 2: *Pump Condition at Fuel Distribution Companies on 2021*

Machine		Class I	Class II	Class III	Class IV Large Soft
in/s	mm/s	Small Machines	Medium Machines	Large Rigid Foundation	Foundation
0.01	0.28				
0.02	0.45		Good		
0.03	0.71				
0.04	1.12				
0.1	1.8		Satisfactory		
0.11	2.8				
0.18	4.5	UnSatisfactory	X21, X24, X25, X33, X34, X35, X70, X72, X82, X85, X86, X87, X88, X89, X90, X106, X107, X		
0.28	7.1			X5, X6, X20, X26, X68, X69, X79,	X91, X92, X94, X105, X108, X109, X112
0.44	11.2	Unacceptabale		X114	
0.70	18				
0.71	28				
1.10	45				

Vibration Velocity Vrms

(Source: Pump condition data processing based on ISO Saverity Rate 10816 - (Istchenko & No, 2006)).

Beside it, pump damage that causes operating downtime also occurs in this fuel oil distribution company. Based on the history of pump damage data, there are 2 pumps experiencing conditions below the standard target of the Indonesian Minister of Energy and Mineral Resources Regulation of the Republic of Indonesia in 2020. These pumps include pump 7 (PX_Blg) with a downtime percentage value of 4.25% and pump 8 (PX_Blg) of 5.17 with the required value should be 2%. The identification of the downtime frequency is shown in equation 1 for the percentage of downtime. Based on the pump equation, the percentage values for the 8 "Unsatisfactory" pumps are obtained which are shown in table 1 bellow.

Table 2: *The results of the company's downtime data processing on 2021.*

Description	*Downtime* Duration (Jam)	Operation Duration (Jam)	Down time (%)	Status (Ministry of energy & mineral - 2020
P.7-PX_Blg	11.25	264.62	4.25	*Under standard*
P.8-PX_Blg	14.25	275.57	5.17	*Under standard*
P.10-FM_Byl	6	842.23	0.712	-
P.11-PM_Sub	3.75	893.52	0.419	-
P.15-PM_Sub	2	900.82	022	-
P.16-PT_Sub	2.5	173.49	1.44	-
P.6-PX_Grm	1.75	719.05	0.24	-
P.5-PX_Grm	2. 5	719	0.34	-

(Source: Pump data processing for downtime on 2021)

II. LITERATURE REVIEW

The literature review becomes a review in the implementation of reliability centered maintenance method on pump for fuel distribution companies. The literature review in this study includes,

Preventive Maintenance

Preventive maintenance or also called preventive is an effort that is carried out before the occurrence of a damage to an item. (Pandi et al., 2017). Preventive maintenance efforts are considered very good in order to prevent an unscheduled stop of a tool. The implementation of these maintenance activities varies greatly, such as providing lubricants to an equipment to program adjustments (Ngadiyono, 2010).

Corrective Maintennace

Corrective maintenance has the opposite meaning of preventive maintenance. This corrective maintenance has the meaning as a maintenance strategy effort which at the time of its implementation is based on the condition of the equipment (Cruz et al., 2020). In its application, corrective maintenance is also known as predictive maintenance which is useful for handling equipment because the treatment on the machine is based on the condition of the damage (Susilo & Suliantoro, 2017).

Planned Maintenance

Planned maintenance or known as planned and scheduled maintenance. This type of maintenance has an effort to prevent major damage to an equipment. The basis of this type of maintenance is referring to the production chain or operation of production (Productive & Rev, 2014). In its implementation, planned maintenance or scheduled maintenance is also known as scheduled maintenance, where maintenance activities are carried out properly and are well organized and have been structured both in maintenance activities and in the implementation schedule (Au-Yong et al., 2014).

Breakdown Maintenance

Breakdown maintenance or maintenance of damage means that an effort in maintenance by means of an equipment can be operated until it is damaged continuously, so that repairs or replacement of spare parts are carried out (Iqbal, 2017). Not only that, maintenance is based on the use of equipment until it breaks down as well as poor maintenance and tends to be maintenance in the form of repairs and replacement of spare parts (Akkinapalli, 2008).

Reliability Centered Maintenance

Reliability centered maintenance or defined as maintenance-focused reliability, is a method of developing, as well as making alternative maintenance strategies based on operating conditions, or equipment problems (Rasindyo et al., 2015). As for the implementation, reliability center maintenance (RCM) is considered as an expert system of a maintenance management system that is implemented through the quality of maintenance of an equipment (Sariyusda, 2018). In addition, the reliability centered maintenance

method is also used in determining the effective maintenance. The actions can be in the form of recommendations in the form of actions that have the potential to reduce the failure of an equipment (Kusuma, 2015). Meanwhile, another understanding explains reliability centered maintenance as an initial method applied in maintenance that focuses on minimizing the failure of an equipment (Robie,2015 1 ., n.d.). The use of the reliability centered maintenance method is to carry out the identification process so that the type or maintenance effort is obtained which is appropriate to be recommended in maintaining an equipment (Hasan et al., 2020). In addition, the use of the reliability centered maintenance method can also be used as a determination of the Crisis component of an equipment because in its implementation, this method is also carried out by means of a total quality management tool (Anggraini et al., 2020). The other use of the implementation of the reliability centered maintenance method is to determine what needs to be done to each physical asset so that it can function normally (Anggayana Basanta et al., 2017).

Pareto Chart

Pareto diagram is a diagram that visualizes a dominant value to a problem in a coherent manner. In another sense, this diagram is defined as an image obtained from the analysis of the problem so that it displays the data in a coherent manner starting from the highest to the lowest stage (Ramadhani et al., 2014).

The Pareto diagram is also interpreted as a data histogram that is implemented by sorting the frequency data so that the cumulative value is obtained to get the percentage of problems (Gunawan & Tannady, 2016).

While the principle of the Pareto diagram is the percentage of problems which from 100% of the problems, in fact 20% of them are important problems and the other 80% is the impact of the problem (Sunarto & Wahito, 2020).

The benefit of the Pareto diagram is as a standard technique in quality control to identify a major problem in management (Apriadi et al., n.d.). Not only that, the Pareto diagram also displays problems based on priority or the number of events that are visualized using graphs, this is done to determine the priority and priority of the problem (Imaroh & Soleh, 2020).

Fish Bone Diagram

Fishbone Diagram is one tool of total quality management which in this tool can be analyzed in the form of root causes of problems that occur. The importance of fishbone diagrams as a development or improvement that is implemented through non-numerical data to identify and coordinate potential root causes that occur.(Nugroho et al., 2017).

In addition, fishbone diagrams are carried out through identification of operating, equipment and environmental factors (Imaroh & Soleh, 2020). The other uses are to find the cause of a problem and explore the potential causes of the problem (Kamal & Sugiyono, 2019). As for the data collection technique in this method, it is done clearly either through the sample or it can also be in the research population (Santoso & Sugiyono, 2017). In its implementation, the root cause analysis of this problem can be carried out using the 5W + 1H analysis method (Nuramzan, 2015).

III. RESEARCH METHODS

The research carried out in this thesis is to carry out an operation management study related to the reliability of Centrifugal pumps through the reliability centered maintenance method and to find out the factors that affect the reliability of Centrifugal pumps by this oil distribution company until a design is obtained to obtain a maintenance method.

Population and Sampel

The selection of the sample in the population becomes part of the action of concentrating the object of this study. In the application of general research, the sampling technique or sampling consists of two techniques, namely probability sampling which is defined as random sampling or random sampling.

This random technique is commonly used for research with a finite population, which means that members of the population are determined beforehand and can provide the same potential for members of the population.

The other sampling techniques are known as non-probability sampling techniques or known as non-random samples or non-random samples and there is a purposive sampling technique, which is a sampling technique.

Research Flowchart

The flow chart of the research which concentrates on the study of operation management related to the reliability of Centrifugal pumps through the reliability centered maintenance method is as follows.

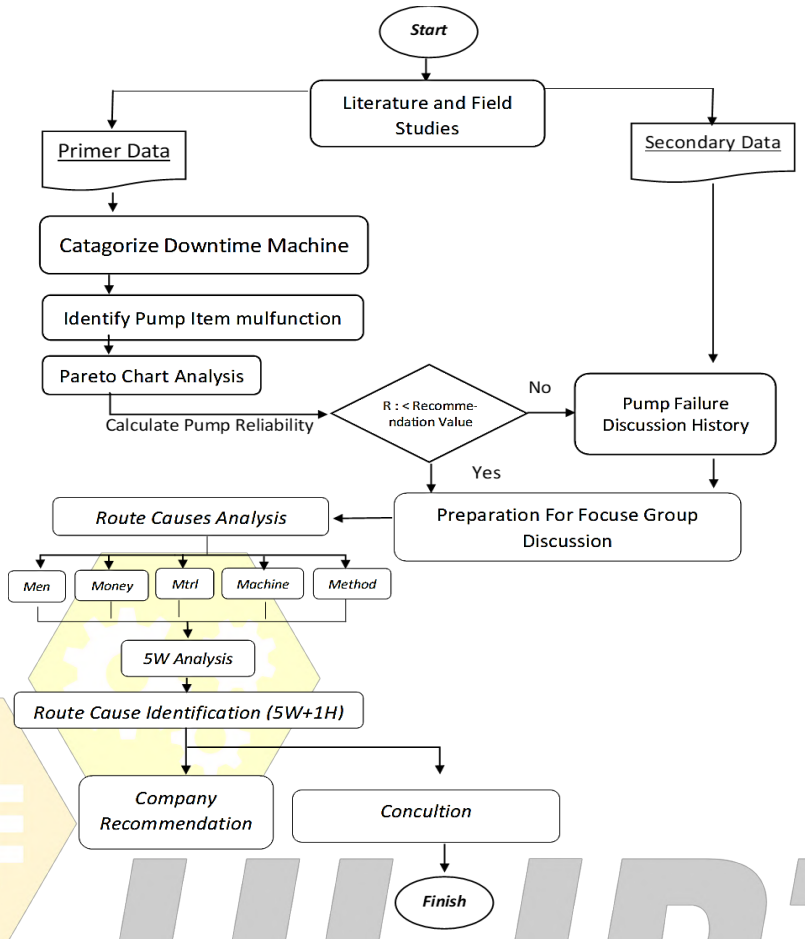

Figure 1: *Research Flow Chart*
(Source: result of self data processing)

The stages in processing data and analysis are the follow-up stages of various data that have been obtained through the search for working methods which are then identified and analyzed in order to achieve the reliability design of the company's pumping equipment. The processing and analysis carried out include the following concentrations,

- Determine the value of the company's pump reliability for the period 2021
- Analyze the factors that affect the reliability of the company's pumps for the 2021 period.
- Design recommended in company pump maintenance and repair.

IV. RESULTS AND DISCUSSION

Determining the Pump Reliability Score on the period of 2021.

The duration of operation of the pump has a different value or duration. In determining the reliability of the pump in the 2021 period, the exponential distribution is where the damage λ (t) is considered constant, which means the rate of damage does not depend on time or the age of components / other factors in the past. The results of the identification of the frequency history of pump damage and the duration of its operation are as follows,

Table 3: *Operation Duration and Frequency of Pump Downtime Period 2021*

No.	Description	Operation (Hours)	Downtime Frequency
1.	Pump 7 (PX_Blg)	264.62	10
2.	Pump 8 (PX_Blg)	275.57	12
3.	Pump 10 (FM Byl)	842.23	7
4.	Pump 11 (PM_Sub)	893.52	4
5.	Pump 15 (PM_Sub)	900.82	2
6.	Pump 16 (PT_Sub)	173.49	3
7.	Pump 6 (PX_Grm)	719.05	2
8.	Pump 5 (PX_Grm)	719	3

(Source: Self Operation Data Processing and Pump Downtime Frequency 2021).

The Formula of the reliability consideration uses the following equation:

R(t) : exp(-λt) (1)
R (t) : Reliability Function
exp : exponential
λt : lamda (t) or Failure Rate
Failure Rate : $\frac{\text{Failure number (Times)}}{\text{Op. Duration (hours)}}$

Based on these data and calculations, found that the pump reliability value is variant, these number is visualized in Figure 2. graph of the company's pump reliability number bellow,

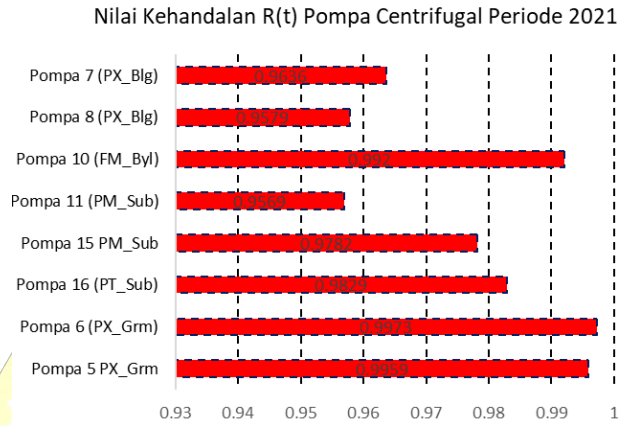

Figure 2: *Graph of Pump Reliability number for 2021*

Based on Figure 2, the graph of the reliability value of the pump in 2021 shows the different reliability values of each pump. As for the graphic above, the lowest reliability value occurs at pump 11 (PM_Sub) with a value of 0.9569 and is followed by other pumps, namely Pump 8 (PX_Blg), Pump 7 (PX_Blg), Pump 15 (PT_Sub), Pump 16 (PT_Sub) , Pump 5 (PX_Grm) respectively. With the highest reliability value for Centrifugal pumps in 2021, namely pump 6 (PX_Grm) with a reliability value of 0.9973.

Analyze the factors that affect the reliability of the company's pumps for the 2021 period.

The action of root cause analyzing for Centrifugal pump problems with the effect or impact of pump alignment through Focuse group discussions by a team of technicians or Centrifugal pump operators and lead engineers at fuel oil distribution companies is an activity to complete a joint analysis to collect and jointly select the root causes of the "effect" that happened which was later agreed upon or mutually agreed upon.

In its implementation, in this Focuse group discussion, sources of problems and solution plans need to be informed for future recommendations. The implementation of this analysis found the root cause of the problem using fish bone diagrams through Focuse Group Discussions to the technicians or operators of the company's Centrifugal pumps as follows:

Table 4: *Root cause identification using 5Why analysis*

ROUTE CAUSE ANALYSIS USING 5WHY						
Case Topic		Pump Alignment			**Audience** : Technical team, operator and lead engineer	
Date Of FGD		: July 20, 2022			Location : Online meeting	
NO	Problem deal	Cause 1st	Cause 2nd	Cause 3rd	Cause 4th	Cause 5th
		Why-1	*Why-2*	*Why-3*	*Why-4*	*Why-5*
1.	*Pump bearing lack of grease*	Forgot to change grease regularly	Replacement of new grease is done when needed (generally every 2 months)	There is no definite schedule for the replacement of the entire pump grease	*Grease is only applied when the stock is running low so that the addition of grease is done when it is available*	

2.	setting the pump PLC too high	Incorrect pump setting/adjustment	Setting / adjustment using the same data equation for all pump motors	Motor settings are made without referring to the motor's default data	Worker concludes all pump settings have the same setting	
3.	Pump location is too close to other pumps	Narrow land area have to cover all pumps	Different pump sizes against initial planning	Dimension reference data when selecting a different pump	There is no updated data bank that can be accessed together	
4.	The meter gauge is not impermeable causing the fluid to collide with the pump	Fluid pressure is too large when passing through the measuring instrument	Product mixing configuration settings distribution changed	No setting/ measurement pressure adjustment		
5.	Pump baseplate anchor material is not strong enough to withstand the pressure	*Anchore is not too stuck or glued into the foundation*	The anchor height that is lacking (anchore) used is too short	Determination of an inappropriate anchor		
6.	There is no pump level alignment checking regulary on	Alignment level checking is only done when	Alignment check stops/reduces system	Pump System must be deactivated	the system cannot work if it is not disabled	The pump is not applied in a

Based on the root cause analysis of the problem through 5 whys with Focuse Group Discussion (FGD) discussions, it was found that the main cause of the problem was based on the 6M category (Machine, Method, Mother earth, man material and measurement) in order to find the main factor of failure in the form of pump miss alignment. Centrifuges which include the following,

- Grease is only applied when the stock is running low so that the addition of grease is done when it is available.
- The pump PLC setting training is only done once for 1 type of pump condition.
- There is no updated data bank that can be accessed together.
- Spool connection area discharge height is too high (Different outlet & inlet dimensions)
- Inappropriate anchor determination planning
- No redundant pump available during repair

Design for company owned pump maintenance and repair

Repair and maintenance for this company's pump is design based on the root analysis of main problem, and developed to implementation of 5W + 1H (What, Why, How, Where, When, Who) method that explained as follows,

- What: What are the main problems or problems that are set as the main targets for improvement based on the categories in the fish bone diagram or root cause analysis of the problems that have been carried out).
- Why (Why the problem or problem can occur)
- How (How is the design or corrective action that needs to be taken to resolve the problem).
- Where (Where the design is certain)
- When (When should a corrective action plan be carried out)
- Who / Who (Who is the best PIC (Person In Charge) and in carrying out the recommended design.

The implementation of this method in order to get the corrective action design carried out for pump maintenance is applied in following table 5. Implementation of the 5W+1H pump maintenance action design below,

Table 5: *Implementation of the 5W+1H pump maintenance action design*

ROUTE CAUSE ANALYSIS USING 5WHY						
Main **Case Topic**		Pump Alignment			**Audience** : Technical team, operator and lead engineer	
Date Of FGD		: July 20, 2022			Location : Online meeting	
NO	Case *What*	Causes *Why*	Corrective Plan *How*	Place *Where*	Time *When*	*Person in charge* *Who*
1.	*Bearing heat pump lack of grease*	*Grease is only applied when the stock is running low so that the addition of grease is done when it is available*	Greasing or lubrication is carried out on a regular basis with sufficient supplies	*Centrifugal Pump Shalter*	As early as possible (July 2022)	Centrifugal Pump technician/operator
2.	Setting or setting the pump PLC too high	Worker concludes all pump settings have the same setting	Providing insight / advice regarding the PLC Pump setting method	Work Area (Control room) / online meeting	As early as possible (July 2022)	*Engineer or Lead Technician / Operator*
3.	The location of the pump is too close to other pumps	There is no updated data bank that can be accessed together	Pump database creation (Google Drive)	Workspace engineer or lead technician / operator.	As early as possible (July 2022)	*Engineer or Lead Technician / Operator*
4.	The meter gauge is not impermeable causing the fluid to collide with the pump	No setting or pressure measurement adjustment	Set the pressure adjustment before doing the test.	*Centrifugal Pump Shalter*	As early as possible (July 2022)	Centrifugal Pump technician/operator
5.	Pump baseplate anchor material is not strong enough to withstand the pressure	Inappropriate anchor determination design	Anchorage design is based on actual data of existing needs.	Workspace engineer or lead technician / operator.	As early as possible (July 2022)	*Engineer or Lead Technician / Operator*
6.	Not checking the pump alignment level on a regular basis	The pump is not applied in a parallel system	Pump system is applied as parallel	*Centrifugal Pump Shalter*	As early as possible (July 2022)	Centrifugal Pump technician/operator

Based on the determination of companies pump maintenance action plan through the implementation of 5W + 1H, the solution of root is obtained, which include the following,

- Regularly greasing or lubricating with sufficient supplies
- Providing insight / advice regarding the PLC Pump setting method
- Creation of pump data bank (Google Drive)
- Perform system pressure adjustment/adjustment prior to measurement.
- Anchorage design is based on actual data of existing needs.
- Pump system is applied as parallel.

So based on the results of this analysis for the preparation of the pump maintenance design in table 5 Implementation of 5W + 1H, the pump maintenance action plan is ploted into the maintenance flow based on the main problem of the pump in the form of the company's pump alignment, which is as follows,

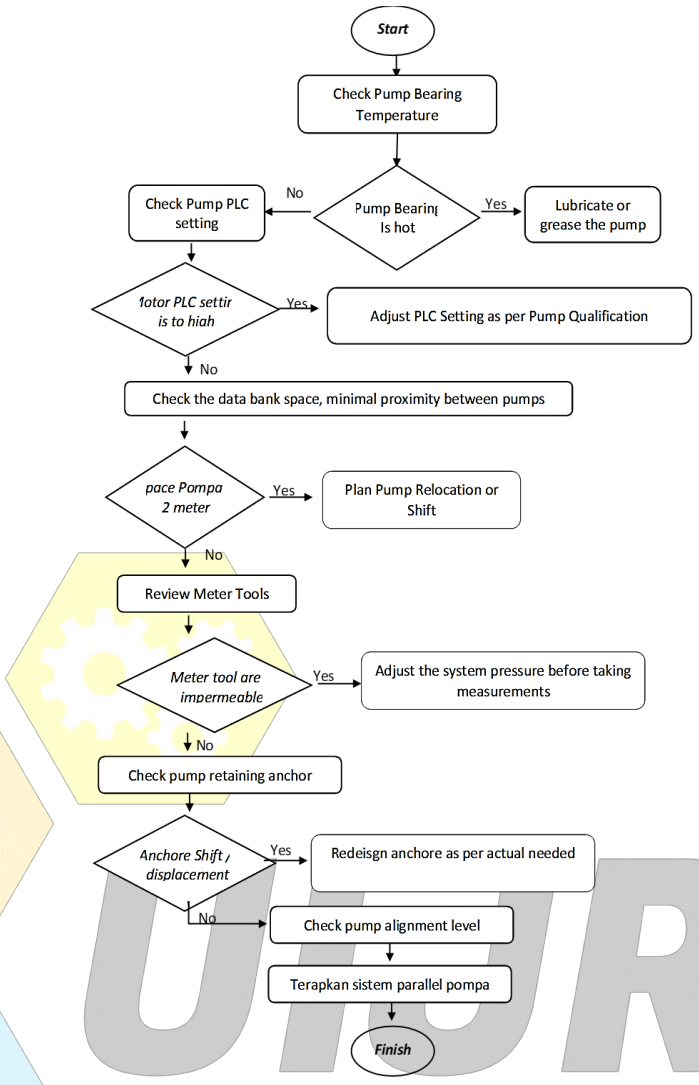

Figure 3: *Design for companies pump maintenance and repair*

Based on Figure 3 the design of the maintenance flow chart for the failure of the Centrifugal pump alignment, the company interprets the design that needs to be done for the failure of the pump after identifying the dominant cause and analyzing the root causes of the pump failure. The presentation of this treatment flow chart design is as follows,

Pump Bearing Temperature Check

This activity is carried out using a temperature gun sensor. If the company's pump bearing has a high temperature, which is greater than 40 degrees Celsius, then immediately apply grease or lubricant because the lubricant is cold and cools parts or especially bearing material that is worn because the absence of lubricant protects the contact against the rotation of the pump bearing.

However, if it is found that the pump bearing does not experience high temperatures, the next process can be continued.

Pump's PLC (Program Logic Control) Checking.

Pump's PLC Inspection are important in pump repair & maintenance because in companies the speed regulation or pump RPM is applied uniformly to pumps with different specifications. The pump speed setting error greatly affects the pump vibration, the higher the pump vibration, the higher the pump alignment potential. As for if the speed or RPM of the pump is right then the next process can be carried out.

Minimum Pump Space Required Checking

Ensuring the minimum distance of the pump aims to obtain information on the distance allowed in the pump housing. If the minimum distance is not achieved, in this case the condition is that the pump has a very close distance between one pump and another, it is advisable to shift or relocate the pump. However, if the miss alignment persists even though the condition of the existing pumps has reached the minimum distance or gap between one another, then you should check the next step.

Pump's Meter Gauge Checking

Meters that are not impermeable cause the fluid flowing in the pump to exert pressure in all directions, causing significant vibrations and pump miss alignment. By checking the pump gauge as early as possible, the tight valve can be repaired and failures in the form of pump alignment can be minimized. However, if the pump miss alignment occurs while there is no damage or problem in the meter system, it can be reviewed on the next measuring instrument.

Anchore's Pump Checking

Anchore has a function to hold the pump shift in maintaining the pump alignment. If the pump does not align due to anchorage damage such as loose, tilted, or poorly embedded in the foundation.

So if it is found that this is the case, it is better to design a better anchore so that it can hold the company's pump. However, if it is found that the anchore condition is still good while the miss alignment condition still occurs, the next process should be carried out.

Pump's Alignment Level Checking

Checking the pump alignment level is done by resetting the pump flatness with the provision of seams so that there is no tilt between pump parts which is carried out by experts based on applicable standards. With this activity, optimization can be carried out as a form of appropriate maintenance and repair in overcoming the main failure of the pump.

So if this does not happen then the recommendation should be to use a parallel system on the pump because by using a parallel system the system can still be operated optimally without having to depend on one pump experiencing unsuccessful operation.

V. CONCLUSION

Conclusions are compiled based on the results of this implementation of the Reliability Centered Maintennace method on the reliability of the company's pumps research. The conclusions in this study are as follows,

1. Company's Pump Reliability Value on 2021

Based on the calculation of the pump reliability value, found that the highest reliability value occurred in pumps with the unsatisfied category, namely pump 6 (Px_grm) with the lowest reliability value occurring at pump 11 (Pm_sub) with a total reliability value of 0.8367.

2. Main Failure Factors of Company's Pumps.

The main factor for pump failure occurs due to miss alignment of the pump. The root causes of the problem include: Pump bearings that lack greasing, PLC (Program Logic Control) pump settings are too high, pump location is too close to other pumps, meter gauges are not impermeable, pump baseplate anchor material is not strong enough to withstand pressure, no checks are carried out pump alignment level regularly.

3. Company pump maintenance & repair design.

The company's pump design is implemented in a yes or no flow diagram which includes: Check the pump bearings, Check the pump PLC, review the company's pump data bank, Check the pump system meter gauge, Do a pump anchore review, Check the pump alignment level or level, Apply the pump system Parallel. And implement Table 5 pump maintenance design 5W+1 H which describes when, where and who is the PIC (Person in charge) pump maintenance team.

Further Research Advice

Based on the research results obtained, the researcher's suggestions for the company are as follows,

The main concern for the company's pumps in the field must be of particular importance to maintain the continuity of the fuel distribution operation. The focus of the management and the technician or operator team on the standards that the company must have for pump reliability such as the Minister of Energy and Mineral Resources Regulation R1-2020 and ISO Saverity Rate 10816 and reliability analysis that focuses on maintenance are important as parameters for companies in carrying out pump maintenance and repairs. So that by applying the standards, designs and analyzes in this study, it is believed that the maintenance and repairs carried out can be more targeted because the main cause of pump damage / failure has been carried out early on.

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