30324

by UMB IJIMEAM

Submission date: 10-Mar-2025 07:39PM (UTC+0700)
Submission ID: 2610627284
File name: IJIMEAM-Sahal_Rifai.docx (258.17K)
Word count: 2893
Character count: 15339

International Journal of Innovation in Mechanical Engineering and Advanced Materials
Vol. 1 (No. 1), 2024, pp. XX-XX
Journal homepage: publikasi.mercubuana.ac.id/index.php/ijimeam
DOI: 10.22441/ijimeam.v6i1.xxx

Analysis of the Effect of Wearing Damage on Centrifugal Pump Performance

Moh Sahal Rifai [1,*], Nanang Ruhyat [1,*]

[1]Department of Mechanical Engineering, Universitas Mercu Buana, Meruya Selatan, Jakarta 11680, Indonesia
*Corresponding Authors: sahalrifai4@gmail.com (MSR), nanang.ruhyat@mercubuana.ac.id (NR)

Abstract

A pump is a mechanical device used to move fluids from a low place to a higher place, in general a pump classified into two, namely positive displacement pump and non-positive displacement pump. Centrifugal pumps are classified as non-positive displacement pump, which works to move fluid from one place to another the other, by converting mechanical energy into kinetic energy. Pump Centrifuges have main components, such as casing, shaft, bearing, coupling and so on impeller. For closed impeller type centrifugal pumps, there are wearing components which functions as a gap between the impeller and casing so that they do not touch when operate. The size of the wearing gap can affect pump performance centrifugal. Damage to wearing can be caused by mechanical damage, corrosion, cavitation and fatigue. Losses resulting from wear damage including: decrease in flow rate, flow pressure and decrease in pump efficiency. This research aims to analyze the problem of wear damage to performance centrifugal pump before and after repairs to wearing components. The data parameters used are pump head, pressure, pump hydraulic power, electric motor power and centrifugal pump efficiency. Data collection and analysis carried out before and after repairs to wearing components. The series of data collection starts from preparation, testing then retrieval and data analysis. Based on data collection before repair with clearance wearing of 1.2 mm, average efficiency value of 8.5%, flow rate of 0.000646 m³/s, then data retrieval after repair with clearance wearing of 0.43 mm, obtained an increase in the average efficiency value to 15.5%, discharge flow of 0.000932 m³/s.

Article Info:
Received: xx xxx 2024
Revised: xx xxx 2024
Accepted: xx xxx 2024
Available online: xx xxx 2024

Keywords:
International journal; mechanical engineering; innovation; advanced material

How to cite:

J. Public, J. Doe and G. Joe, " International journal of innovation in mechanical engineering and ad-vanced materials: Author guidelines," *Int. J. Innov. Mech. Eng. Adv. Mater*, vol. 6, no. 1, pp. 1-10, 2024

1. Introduction

Industrial development in Indonesia is very rapid along with technological advances and the construction of large companies engaged in various sectors, such as agriculture, education, textiles, food, mining and petrochemicals. The petrochemical industry is an industry that produces organic chemical products with basic raw materials from oil and gas processing, coal, and biomass-based oleochemicals [1]. To support production process activities, the company has main equipment such as pumps, compressors, heat exchangers, furnaces, vessels, distillation columns, condensers, coolers, separators, valves, piping and instrumentation [2]. Pumps are mechanical equipment driven by electric motors, machines or the like to move fluids from one place to another by rotating or moving fluids aimed at increasing pressure, speed and discharge [3].

Centrifugal pumps have several important components, one of which is the impeller. Impeller has an important role in raising the head and capacity, so that it can affect the efficiency of the centrifugal pump [4], based on the type, impellers are divided into three, namely closed impeller, open impeller and semi open impeller [5]. In the closed mpeller type, there is wearing, this component is a supporting component that is very important to maintain the performance of centrifugal pumps, which are usually installed on the stationary side of the pump casing [6]. Wearing which serves to minimize fluid leakage that passes through the front and back of the impeller by reducing the gap between the impeller and the casing, if the gap is getting bigger it can affect the flow rate of the pump. To maximize the performance of centrifugal pumps, it is necessary to minimize the flow of liquid leaking through the gap between the impeller and the casing [7].

There are several causes of wearing damage, mechanical damage, cavitation, corrosion and fatigue [8]. Change in pressure value and flow rate at each valve have influence, where it gets smaller valve opening then head increasingly produced big, but comparable inversely with the flow rate resulting from [9]. Free clearance between the volute and the impeller (wearing) very important, it can affect flow rate and worsen performance pump. Thickness very clearance affect volumetrics and hydraulic efficiency because there is the leak excessive [10], then the relationship between discharge with shaft power the pump is proportional straight, the greater the discharge the flow then gets bigger pump shaft power [11]. In this study, a comparative analysis of the efficiency of centrifugal pumps will be carried out before and after the repair of wearing components. Based on the explanation above, the author decided to choose the title of the final project "Analysis of the Effect of Wearing Damage on Centrifugal Pump Performance".

2. Methods

2.1. Research stages

There are several stages that need to be done in research. This research is carried out starting with choosing the object of research, literature study to collect information that is appropriate to the research. The next process is to test the performance of centrifugal pumps with different clearance wearing variations and analyze the data obtained from the test results.

Some of the data obtained in this test, namely pump head, brake horse power and centrifugal pump efficiency. Data analysis using theoretical formulas related to centrifugal pump performance. The result of this study is to be able to determine the ideal and standard wearing clearance on centrifugal pumps.

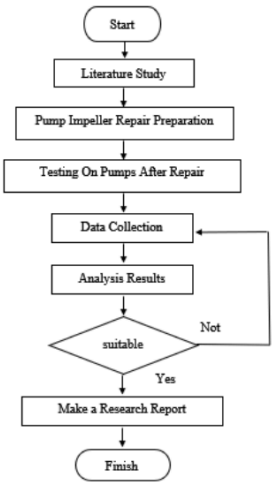


Figure 1. Research flow chart

2.1. Pump specification

Based on the results of data collection in the field, centrifugal pumps are used with specifications that will be described in Table 1, as follows:

Table 1. Specification Centrifugal Pump

No.	Deskripsi	Spesifikasi
1.	*Maker*	Ebara Corporation
2.	*Motor Power*	5.5 kW
3.	*Shaft Power*	3.59 kW
4.	*Current*	9 A
5.	*Voltage*	380 V
6.	*Cos ø*	0.90
7.	*Capacity*	3.5 m^3/h
8.	*Head*	50 m
9.	*Speed*	2920 rpm
10.	*Type*	*Closed Impeller*
11.	*Efficiency*	16.5 %

2.2. Centrifugal Pump Head

In designing a pump system, the first step is to know the discharge and head needed to drain the liquid to be pumped. The pump head that must be provided to drain the planned water discharge can be determined from the installation conditions to be used by the pump, the total heat of the pump can be calculated by the equation [9] :

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

Description:
H = Total pump head (m)
ΔP = Pressure discharge – pressure suction
ρ = Density of liquid (kg/m^3)
g = Acceleration of gravity ($9.8\ m/s^2$)

2.3. Water Horse Power

Hydrolysis power is the power generated from a centrifugal pump to drain liquid discharge at a certain head [10] The hydrolysis power can be calculated by the following equation:

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

$$WHP = \frac{y \,.\, H.\, Q}{1000}$$

Description :
WHP = Water horse power (kW)
Y = Specific gravity of water (N/m^3)
Q = Flow discharge (m^3/s)
H = Total pump head (m)

Brake Horse Power

Brake horse power is defined as the actual shaft power required to drive the pump. The power entering the pump shaft is generated from the driving engine (driver), the shaft power can be calculated by the following equation:

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

$$BHP = \frac{WHP}{\eta \text{ Pump}}$$

Descripction :
BHP = Brake horse power (kW)
WHP = Water horse power (kW)
η Pump = Pump efficiency

Failure Mode and Effect Analysis

Failure Mode and Effect analysis is an engineering technique used to identify, define, and eliminate failures, errors or known problems from systems, designs and processes that form values. There are three aspects to determining failure [11] Occurrence, Severity and Detection, after an assessment of each aspect of the activity, each value will be multiplied to obtain the value of the risk priority number. The value is used to compare the causes identified during the analysis of potential problems. The RPN calculation has the following formula [12] :

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

RPN = Occurrence x severity x detection

Reliability Machine

To calculate the reliability value of a centrifugal pump, it must first be known the value of the mean time between failure (MTBF) and the failure rate value [13].

Mean time between failure (MTBF) is a value that shows how long the engine can operate without experiencing problems or damage. The MTBF calculation formula is as follows:

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

MTBF = $\frac{Operating\ \ Time}{Failure}$

Failure rate is the probability of a failure per unit time at a time interval. The failure rate calculation formula is as follows:

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

$\lambda = \frac{1}{MTBF}$

After obtaining the MTBF value and failure rate, the reliability value can be calculated using the following formula:

$$H = \frac{\Delta P}{\rho g} \quad (1)$$

$R = e^{-((\lambda)(t))}$

Description :

R = Reliability
e = 2.71828182846
λ = Failure rate
t = Assumption of time of use of centrifugal pumps

3. Results and Discussion

3.1. American Petroleum Institute 610 standard

API 610 is the standard for centrifugal pumps used in the oil and gas industry. This standard specifies design, material, manufacturing, inspection and testing requirements to ensure pump safety, reliability and availability. Some of the important features include casing design, shaft, impeller, shaft deflection, bearing design life, vibration.

Table 2. Clearance wearing standard

Diameter of rotating member at clearance mm	Minimum diametral clearance mm			
	Manufacturer's Std (0.75 x API 610)	Non metallic	API 610	API 610 "Hot"
< 50	0.188	0.125	0.250	0.375
50 to 64.99	0.210	0.140	0.280	0.405
65 to 79.99	0.225	0.150	0.300	0.425
80 to 89.99	0.248	0.165	0.330	0.455
90 to 99.99	0.263	0.175	0.350	0.475
100 to 114.99	0.285	0.190	0.380	0.505
115 to 124.99	0.300	0.200	0.400	0.525
125 to 149.99	0.323	0.215	0.430	0.555
150 to 174.99	0.338	0.225	0.450	0.575
175 to 199.99	0.360	0.240	0.480	0.605
200 to 224.99	0.375	0.250	0.500	0.625
225 to 249.99	0.398	0.265	0.530	0.655
250 to 274.99	0.413	0.275	0.550	0.675
275 to 299.99	0.435	0.290	0.580	0.705

Based on the API 610 table above, the optimal wearing clearance standard used is 0.43 mm.

3.2. Centrifugal pump performance before repairs wearing impeller

Observations and data collection are carried out every 3 hours with average calculations for two days, namely 11 – 12 October 2023. The following are the results of observations and data collection on the performance of centrifugal pumps.

Table 3. Pump performance data before repair

Time (WIB)	head (meter)	bhp (Watt)	whp (watt)	η
09.00	40.91	3427	302	0.09
12.00	41.79	3165	327	0.10
15.00	41.79	3251	314	0.10
18.00	40.02	3517	326	0.09
21.00	40.46	3427	316	0.09
00.00	40.20	3480	277	0.08
03.00	39.93	3427	288	0.08
06.00	39.66	3517	261	0.07
09.00	39.40	3427	246	0.07

`

The table above is the result of observations from centrifugal pumps before repairs, where the average value of centrifugal pump efficiency is 8.5%.

3.3. Inspection and repair results based on the type of pump damage

The inspection and repair process of centrifugal pumps begins with the measurement of the run out shaft, wearing impeller and pump casing, bearing housing and visual observation of the condition of the bearing.

Table 4. Damage inspection and repair of pumps

Component	Inspection	Repairement
Wearing	Clearance is out tolerance (1.2 mm)	Fabrication wearing with lathe machine, by total gap 0.43 mm (American Petroleum Institute 610 Standard)
Run Out Shaft	Shaft has bend at impeller side (0.8 mm)	Fabrication shaft with lathe machine
Housing Bearing	Tolerance is acceptable (+0.01mm ~ +0.02 mm)	No repair
Bearing	No damaged, check by visual	Replace bearing, avoid defect during process inspection

Alignment	Misalignment on horizontal side of 0.23 mm and axial side of 0.2 mm	Re-alignment with dial gauge, max result on the horizontal and axial sides of 0.05 mm

3.4. Results of observation and data collection after improvement

Observation and data collection after repairing the wearing impeller and shaft, carried out for two days on October 13 – 14, 2023. The following are the results of observations and data collection after the pump has been repaired:

Table 5. Pump performance data after repair

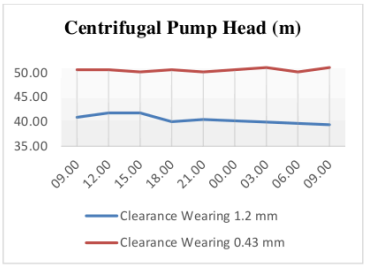
Time (WIB)	head (meter)	bhp (Watt)	whp (watt)	η
09.00	50.58	3517	536	0.15
12.00	50.58	3427	524	0.15
15.00	50.13	3462	531	0.15
18.00	50.58	3427	524	0.15
21.00	50.13	3517	548	0.16
00.00	50.58	3480	542	0.16
03.00	51.02	3427	529	0.15
06.00	50.13	3517	548	0.16
09.00	51.02	3427	529	0.15

The table above is the result of observations from centrifugal pumps before repair, where the average value of centrifugal pump efficiency rose from 8.5% to 15.5%.

3.5. Correlation of Clearance Wearing to Centrifugal Pump Head

The data from monitoring and calculation using the equation H = (Pdischarge-Psuction) / (p.g) obtained from data before and after repairs to the wearing impeller is real data that is processed and compared to centrifugal pump heads.

Figure 2. Correlation graph of wearing clearance to pump head



Based on Figure 2., the correlation graph of clearance wearing to the pump head shows that clearance affects the total pump head. The average value of a head with a wearing clearance of 1.2 mm is 40.45 m, while the average value of a head with a wearing clearance of 0.43 mm is 50.52 m. Based on the explanation above, it can be concluded that the smaller the wearing clearance, the larger the pump head produced.

3.6. Correlation of Wearing Clearance to Centrifugal Pump Efficiency

The correlation between clearance and pump efficiency is obtained from the results of monitoring and calculations using the equation $\eta = WHP/(BHP_2) \times 100\%$, which is obtained based on activities before and after repairs to the wearing impeller component.

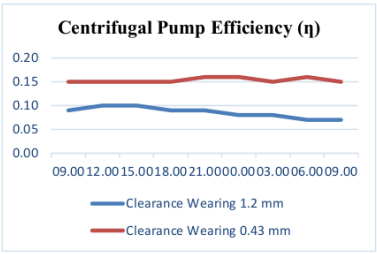


Figure 3. Graph of the correlation of wearing clearance to pump efficiency

Based on Figure 2., the graph of the correlation of clearance wearing to pump efficiency shows that clearance affects pump efficiency. The average value of pump efficiency with a wearing clearance of 1.2 mm is 8.5%, while the average value of pump efficiency with a wearing clearance of 0.43 mm is 15.5%.

3.7. Impeller reliability level

Before creating an FMEA table, it is required to have historical data as a reference to find out the basis of the damage and the resulting consequences. After observation, a failure was found in the impeller component of the centrifugal pump as shown in the following table:

Table 6. FMEA impeller sentrifugal pump

Functional failures	Effects of Failure	RPN
Wearing has worn out	decreased pump efficiency	210
Clogging caused by dirt	Unstable pressure and discharge	96
Erosion impeller	The pump will not work	96
Inside diameter worn out	**excessive vibration**	**108**

In calculating the reliability of the impeller on centrifugal pumps, it is carried out based on operating hours and all parts of the impeller that have failed. To calculate the reliability of the impeller, the author took assumptions based on after the centrifugal pump worked at 500, 1000, 1500, 2000, 2500, and 3000 hours. In the table below, we will explain the failure rate in the impeller:

Table 7. Failure rate impeller

Functional failures	(λ)
Wearing has worn out	0.000228
Clogging caused by dirt	0.000285
Erosion impeller	0.000114
Inside diameter worn out	**0.000057**

Then the reliability value on the centrifugal pump impeller is obtained based on the operational time of the centrifugal pump, can be seen in the table below

Table 8. Reliability of the impeller

Operating Hours	Reliability
500	91.8%
1000	84.28%
1500	76.8%
2000	69.24%
2500	61.7%
3000	**54.20%**

In this study, the reliability results of the centrifugal pump impeller were 91.8% after 500 hours of operation, 76.8% after 1500 hours of operation and 54.2% after 3000 hours of operation. Based on the Indonesian Industrial Standard (SII), the reliability limit of the machine operating is 70%.

4. Conclusions

Based on research, clearance wearing is very influential on the performance of centrifugal pumps. There are two variations of wearing clearance, namely with a clearance of 0.43 mm and a clearance of 1.2 mm, obtained average efficiency results of 15.5% and 8.5%. The average flow discharge obtained in the study with a wearing clearance of 0.43 mm was 3.45 m^3/h, then the average flow discharge with a wearing clearance of 1.2 mm was 2.33 m^3/h. The pump head obtained in this study with a wearing clearance of 0.43 mm is 50.52 m, then the pump head obtained with a wearing clearance of 1.2 mm is 40.45 m. To achieve reliability values above 70%, preventive maintenance is always carried out on centrifugal pumps.

Acknowledgements

Authors would like to express his deepest gratitude to the Department of Mechanical Engineering, Universitas Mercu Buana, for supporting the research activities.

References

[1] Hariady, S. (2014). Damage Analysis of Centrifugal Pump 53-101C WTU Sungai Gerong PT. Pertamina RU III Plaju. Journal of Technology Dissemination, 2(1).
[2] Mustaghfirin Amin, M. (2014). Gas Turbine Engine Class XI Semester 4. Jakarta : Ministry of Education and Culture.
[3] Thoharudin, A. S. N., & Unjanto, S. (2014). Optimization of Compressive Height and efficiency of centrifugal pumps with changes in the number of impeller blades and impeller exit angle (β2) using computational fluid dynamics simulation. In Proceedings of the National Seminar on Science & Technology Applications (SNAST) ,Vol. 15.
[4] Imam Purwa Adisasmita (2018). Centrifugal Pump Impeller Planning 16 Inch Diameter On Cutter Suction Dredger (CSD) by Using Solidwork (Thesis, Sepuluh Nopember Institute of Technology Surabaya).
[5] Wen-Guang Li (2016). Effect of viscosity on turbine mode performance and flow of low specific speed centrifugal pump. In Applied Mathematical Modelling ,Vol. 60, 904-926
[6] Metin Guner & Mehmet Melih (2020). Centrifugal pump design materials and specifications. In Eskişehir Technical University Journal of Science and Technology B- Theoretical Sciences, Vol 8(1), 143-153.
[7] Sularso, H. T. (1983). Pumps and Compressors, Selection, Maintenance and Usage. Jakarta : Pradaya Paramita Publisher.
[8] Made Suarda (2017). System Performance Investigation Slow Sand Water Filter with Water Flow from Bottom toTop to ImproveRural Clean Water Quality. National Conference on Hospitality Engineering,Vol 4(1), 147-151.
[9] Aan Fakhruddin & Razali (2020). Analysis of the Causes of Damage to Centrifugal Pump Impeller Using the FMEA Method at PT. Meskom Agro Sarimas. Journal of Transmission Vol , 16(2).
[10] Agus Setyo & Ahmad Ali (2016). Analysis of Decreasing Sodium Hydroxide Pump Capacity with a Capacity of 60 m^3/h. Journal of Engineering Science and Applied Vol , 5(1).
[11] D. H. Stamatis (2003). Failure mode and effect analysis:FMEA from theory execution, Milwaukee: American Society for Quality, Quality Press.
[12] M. Ben-Daya, S. O. Duffua, A. Raouf, J. Knezevic and D. Ait-Kadi (2009). Handbook of Maintenance
[13] N. Shivananda (2015). World Class Maintenance Management, New Delhi: McGraw Hill Education (India) Ltd

30324

ORIGINALITY REPORT

7%	5%	2%	6%
SIMILARITY INDEX	INTERNET SOURCES	PUBLICATIONS	STUDENT PAPERS

PRIMARY SOURCES

1	Submitted to United International University Student Paper	4%
2	Submitted to Universitas Brawijaya Student Paper	1%
3	talenta.usu.ac.id Internet Source	1%
4	1library.net Internet Source	1%

Exclude quotes	On	Exclude matches	< 17 words
Exclude bibliography	On		