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Research article

Efficiency Analysis of the 946–P-1–B Centrifugal Pump in PT Installation and Shipment Area. Pertamina Refinery Unit II Production Sungai Pakning

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A B S T R A C T

This study examines the performance of centrifugal pumps, particularly the 946-P-1B pump used for transferring crude oil. The objective is to analyze its efficiency and operational characteristics. The problem is addressed using calculation data to evaluate the relationship between shaft power (Pout) and efficiency. Results show that the pump's efficiency ranges from 47% to 55%, indicating its capacity to convert hydraulic energy into shaft power. Efficiency was observed to increase with higher shaft power. These findings underscore the importance of optimizing shaft power to improve pump performance in industrial applications.

1. INTRODUCTION

A pump is a device used to flow fluid from one location to another by increasing the fluid pressure, and improving the fluid flow helps overcome obstacles in the flow, such as pressure differences, height differences, or occurrences—one of the pumps at PT. Pertamina RU II Sungai Pakning is a Centrifugal Pump 946-P-1-B, which acts as a tool to heat Reduced Crude from the tank to the Crude Oil Unit (CDU). The 946-P-1-B Centrifugal Pump is a between-bearing type pump. The meaning of the tag number 946-P-1-B on this centrifugal pump is that the number 946 shows that this pump is located in area 946, namely the tank installation and shipping area, P is the initial from the word pump, and 1 is the pump number, while the initials A/B function to indicate that there are two pumps. In this area are pump A and pump B. However, only one pump is operating; the rest are as a reserve or reserve.

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Figure 1. Centrifugal Feed Pump 946-P-1B

The PT PERTAMINA RU II construction project on the Pakning River is supported by a centrifugal pump machine whose function is to move water from one place to another based on pressure differences. The tailings from the 101 T-1 guard tower are removed by a centrifugal pump and sent to the product tank. Therefore, knowing all the damage and problems with pump operation is one of the main points for overcoming current issues. Count Pump efficiency is critical to understanding the range of work that the pump can do. Damage or failure to the pump can hamper or even stop the production process. Machine downtime, or when the machine has to stop operating, is a problem in the production process.

2. LITERATURE

Centrifugal pumps are pumps that work using the principle of centrifugal force. This force acts on components that rotate on their axis. External power is supplied to the pump shaft to rotate the impeller in the water. Therefore, the blades push the water into the impeller and rotate. Due to centrifugal force, water flows from the center of the impeller to the outside through channels between the blades. Here, the water pressure is higher. In addition, the speed increases because the water accelerates. This is the water that leaves the impeller and flows from the pump through the nozzle. This nozzle converts part of the flow head into a pressure head.

Head losses and efficiency analyses, providing insights into total head, power consumption, and efficiency calculations [1]. Performance curves, including head, efficiency, and brake horsepower, are crucial for understanding pump behavior. [2]. Changes in frequency have an impact on pump efficiency, motor efficiency, and power losses. [3]. The energy performance of pumps affects various operating conditions. [4]. The hydraulic performance of centrifugal pumps relates to head, flow rate, and efficiency. [5].

Significant break loss-of-coolant accidents are relevant to the small break loss-of-coolant accident analyses. [6]. Correlation between decline in the efficiency of pumps over time and suggests maintenance strategies to improve performance. [7]. Pressure pulsation induced by rotor-stator interaction in a nuclear reactor coolant pump (RCP) is a critical study due to the complex and high-stakes environment in which these pumps operate. [8]. Comprehensive report that provides detailed technical analyses and results to support the development and implementation of energy efficiency standards for various consumer products and commercial and industrial equipment [9]. Several key aspects that are crucial for understanding the dynamics of turbulent mixing in such aquatic environments [10].

Optimizing centrifugal pump design using CFD and artificial intelligence algorithms was one of the options to improve efficiency, head, and power. [11]. The performance analysis of centrifugal pumps using mathematical models to predict efficiency, failure rates, and repair cycles, which can be applied to pump efficiency in industrial settings [12]. The impact of various impeller configurations and operating conditions on the efficiency of centrifugal pumps used in oil delivery, providing insights into performance optimization techniques [13].

In this context, centrifugal machines are often referred to as working machines, with the function of the blower to provide work to the water so that the energy in the water increases. The difference in force per mass, which is the total head of water between the suction and discharge pipes of the pump, is known as the total head of the pump.

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Figure 2. Centrifugal Pumps

The pump performance parameters are explainde as follows:

2.1 Pump power

Pump power can be obtained using the formula:

$$P = \frac{\rho.g.Q.Hp}{746.\eta_p} \quad (1)$$

Where:
ρ: Fluid density (kg/m^2)
g: gravitational acceleration (m/s^2)
Hp: Total heads (m)
η_p: Pump efficiency (%)

2.2 Hydraulic power

As for the formula for the power generated, it can be formulated as:

$$WHP = \frac{\gamma.Q.H_p}{1000} \quad (2)$$

Where:
Q: Debit (m^3/s)
Hp: Head Total (m)

2.3 Pump Efficiency

The pump cannot convert all kinetic energy into pressure energy because some of the kinetic energy is lost in the form of losses. Pump efficiency is the ratio between hydrolysis power, usually more significant than the power produced by the pump-to-pump fluid. Pump efficiency, generally expressed as a percentage, is the ratio between the pump system's input and output power.

$$\eta_p = \frac{WHP}{BHP}.100\% \quad (3)$$

2.4 Differential Head

To determine the differential pressure, it can be formulated:

$$diff.press = Pd - Ps \quad (4)$$

Where:
Pd: Exhaust side pressure (kg/cm^2)
Ps: Suction side pressure (kg/cm^2)
So,

$$Z = \frac{10.(Diff.\ Press)}{SG} \quad (5)$$

Where:
Z: Differential Head (m)
SG: Specific Gravity

2.5 Drive Motor Power

Power is a measure of the energy used per unit of time. The pumping system has three types of power: water power (Water Horse Power), axle power (Brake Horse Power), and electric power used to operate the pumping system. The amount of power can be calculated using the formula that has been determined as follows:

$$BHP = \frac{\sqrt{3}.V_{Ph}.I.Cos\,\emptyset}{1000} \quad (6)$$

Where:
BHP: Drive Motor Power (kW)
V_{Ph} : Voltase Motor (Volt)
I: Strong currents (Ampere)
Cosϕ: Power factor (dimensionless), where
ϕ is the phase angle between voltage and current.

2.6 Head Total

The head is the height of the lifting energy or can be expressed as a unit of pump energy per fluid weight; for the total head, it is the head that shows the difference in height between the surface of the liquid that is sucked in by the pump (suction reservoir) and the surface of the substance that is given pressure by the pump (discharge reservoir):

$$Hp = \frac{P_d - P_s}{\gamma} + \left(\frac{vd^2 - vs^2}{2g}\right) + Z \quad (7)$$

Where:
Hp: Head Total (m)
Vd: Discharge Speed (m/s)
Vs: Suction Speed (m/s)
γ: density times gravity

2.7 Fluid flow speed in a pipe

According to the continuity equation, the flow velocity in a steady flow, which does not depend on time, is:

a. Suction speed

$$Vs = \frac{Q}{\frac{\pi}{4} . D_s^2} \quad (8)$$

Where:
Ds: Diameter suction (m)

b. Discharge Speed

$$Vd = \frac{Q}{\frac{\pi}{4} . D_d^2} \quad (9)$$

Where:
Dd: Diameter discharge (m)

3. METHODOLOGY

A pump is an energy conversion machine that changes the form of shaft mechanical energy into specific energy (head) of a fluid in the form of water. The mechanical energy of a pump, which shows the ability of a pump to lift fluid to reach a certain height, is in the form of a pump head, indicated by the magnitude of the difference between the fluid energy on the suction side and the fluid energy on the pressure side.

The method used to measure pump efficiency is to compare the power put into the pump with the power it produces. In evaluating the performance of the 946-P1-B pump, the pump specifications are as follows:

Table 1. Pump 946-P1-B "operating conditional" specifications

No	DATA	Mark
1	Pump manufacture	SHIN MACHINERY CO. LTD
2	Pump service	CRUDE FEED PUMPS
3	NPSHr	8,4 m
4	NPSHa	4,5 m
5	Pressure suction	10,2 m
6	Pressure discharge	261,8 m
7	Efficiency	70%
8.	Diff. Head	251,6 m
9	Pump temperature	40 ^{0}C
10	Specific gravity	0,85
11.	Capacity	350 m^3/h

The construction specifications table for the 946-P-1-B Centrifugal Pump can be seen in Table 2 below:

Table 2. Construction specifications for 946-P-1-B Centrifugal Pump

No	DATA	Mark
1	Suction pipe	10 inches
2	Discharge pipe	10 inches
3	Case mount	Centerline
4	Split	Axial, DBL
5	Impeller diameter	13 inches
6	Type	Closed
7	Bearing type	Radial ball, thrust ball
8.	Coupling	Metastream/TSK spacer
9	Mechanical seal	Flexibox

The specifications for the 196-P-1-B centrifugal pump "motor driver" is depicted in Table 3.

Table 3. Specifications for the "motor driver" Centrifugal pump 196-P-1-B

No	DATA	Mark
1	Motor power	320 kW
2	Motor rotation	2650 RPM
3	Motor voltage	3300 Volt
4	Phase	3
5	Current	66 A (full load)
6	Efficiency	94%
7	Power factor cos φ	0.93 (full load)

Fluid energy is the sum of pressure, kinetic, and energy due to elevation. Pump specifications are expressed in the amount of fluid that can be flowed per unit of time (pump flow or capacity) and head (lifting energy height). The method compares the input power with the output power produced by the pump. So, several parameters or data are needed, including discharge pressure (kg/m2), flow (m3/s), voltage (V), and current strength (A). The data from the observations can be seen in the Table 4.

Table 4. Observation Data

No	Data Collection Date	Flow (m^3/s)	Density (Kg/m^2)	Discharge Press (kg/m2)	Voltage (V)	strong currents (A)
1	17 Januari 2024	0,042	928,9	30	3300	33
2	18 Januari 2024	0.038	928,9	30	3300	33
3	19 Januari 2024	0.040	928,9	30	3300	33
4	20 Januari 2024	0.041	928,9	30	3300	33
5	21 Januari 2024	0.030	928,9	30	3300	33

The calculations that can be done from the data obtained are as follows:

Suction Speed

The calculation of suction speed where the suction diameter is ten into 0.254 m can be calculated using the formula that has been discussed as follows :
Diameter suction =10 in = 0.254 m

$$\mathrm{Vs} = \frac{0.042\ \mathrm{m^3/s}}{\frac{\pi}{4}.\ (0.254\ \mathrm{m})^2} = 0.829301\ \mathrm{m/s}$$

Discharge Speed

The discharge velocity calculation where the discharge diameter is ten into 0.254 m can be calculated using the following formula :

$$\mathrm{Vd} = \frac{0.042\ \mathrm{m^3/s}}{\frac{\pi}{4}.(0{,}254\ \mathrm{m})^2} = 0.829301\ \mathrm{m/s}$$

Differential pressure

The differential pressure calculation is as follows :

$$\mathrm{Diff.\,press} = (30\ \mathrm{kg/cm^2}) - (1.02\ \mathrm{kg/cm^2})$$
$$\mathrm{Diff.\,press} = 28.98\ \mathrm{kg/cm^2}$$

Differential Head

Once known diff. Press then diff can be calculated. The head. The differential head calculation is as follows :

$$Z = \frac{10\ .(28{,}98\ \mathrm{kg/cm^2})}{0{,}85} = 340.94\ \mathrm{m}$$

Head pump

The pump head calculation is as follows :

$$\mathrm{Hp} = \frac{30 - 1{,}02}{9103.22} + \left(\frac{(0.829301)^2 - (0.829301)^2}{2\ .\ 9.8}\right) + 340.94$$
$$\mathrm{Hp} = 340.943\ \mathrm{m}$$

Hydraulic power

The calculation of hydraulic power is as follows :

$$\mathrm{WHP} = \frac{9103.22\ .\ 0.042\ .\ 340.943}{1000} = 130.355\ \mathrm{kW}$$

Drive motor power

The calculation for the power of the driving motor is as follows :

$$\mathrm{BHP} = \frac{\sqrt{3}\ .\ 3300\ .\ 33\ .\ 0.93}{1000} = 175.412\ \mathrm{kW}$$

Pump efficiency

After finding the hydraulic and driving motor power, the hydraulic and driving motor power can be compared using a predetermined equation. The equation is as follows:

$$\eta_p = \frac{130{,}355}{175{,}412}\ .100\% = 74.31\%$$

Pump power

The pump power can be calculated using the following equation:

$$P = \frac{928.9\ .\ 9.81\ .\ 0.042\ .\ 340.943}{746\ .\ 0.7431} = 235.387\ \mathrm{HP}$$

4. RESULTS AND DISCUSSION

The data resulting from the calculations that have been carried out are shown in the Table 5.

Table 5. 946-P-1-B Pump Efficiency results in data

No	Data Collection Date	Flow (m^3/s)	Discharge Press. (kg/cm^2)	Diff. head (m)	Strongest Current (A)	Head Pump (m)	Motor Power (kW)	Hydraulic Power (kW)	Pump Power (Hp)	Efficiency (%)
1	17/01/2024	0.042	30	340.94	33	340.943	175.412	130.355	235.387	74.31
2	18/01/2024	0.038	30	340.94	33	340.943	175.412	117.940	235.362	67.24
3	19/01/2024	0.040	30	340.94	33	340.943	175.412	124.147	235.392	70.77
4	20/01/2024	0.041	30	340.94	33	340.943	175.412	127.51	235.390	72.54
5	21/01/2024	0.039	30	340.94	33	340.943	175.412	133.458	235.395	69

Efficiency is the level of working ability of a tool. The efficiency level for the 946 P-1 B pump ranges from 67% to 74%. The calculation data shows that the increase and decrease in pump efficiency are where the pump efficiency is directly proportional to the hydraulic power, where the higher the hydraulic power or Pout, the higher the pump efficiency. Decrease and increase in efficiency can be caused by differences in inflow and product density, which change daily.

According to (Akhmad M.H. 2014), when the pumps operate individually, the efficiency of pump 2 reaches 60.87%; this value is lower than the efficiency of pump 2 recorded in the "Pump Performance Test Record" of 70%. Meanwhile, the efficiency of pump 5 reached 61.87%. The decrease in pump efficiency is caused by several factors, such as sub-optimal system design, cavitation, wear and tear, electrical installations that do not meet standards, and inappropriate mechanical and electrical operating patterns. In addition, the most significant decrease in efficiency occurred in pump 4, where the efficiency of pump 4 was 69.87%, which was much lower than the efficiency recorded in the "Pump Performance Test Record" of 84%. This is because pump 4 operates at a lower capacity, namely 5936.274 (m^3/hour), compared to the capacity recorded in the "Pump Performance Test Record" of 7380 (m^3/hour). When pumps 2, 4, and 5 operate simultaneously, the total pump efficiency peaks at 15.00, namely 49.8%.

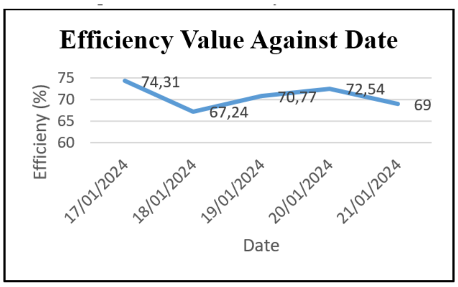

Figure 3. Efficiency Value Against Date Graph

Figure 3 is a graph of the data collection date where calculations have been carried out to obtain efficiency from the data taken. Meanwhile, from 17 to 21 January 2024, various efficiencies were found, namely 74.31%, 67.24%, 70.77%, 72.54%, and 69%.

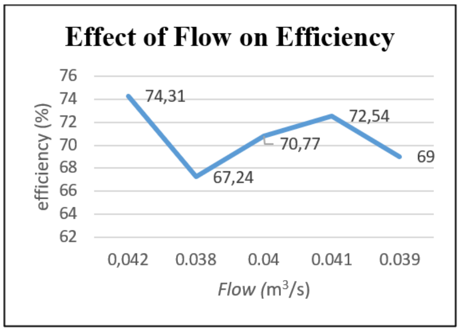

Figure 4. Relationship of Discharge vs Efficiency Graph

From Figure 4, we can see the effect of hydraulic power on efficiency, where at a hydraulic power of 130.355 kW, the efficiency is 74.31%. At a hydraulic power of 117.940 kW, the efficiency is found to be 67.24%; at a hydraulic power of 124.147 kW, the efficiency is 70.77%; at a hydraulic power of 127.51 kW, it has an efficiency of 72.54%. At a hydraulic power of 133.458 kW, it has an efficiency of 69%. Here, we can see that hydraulic power is directly proportional to efficiency, where the more significant the discharge, the greater the efficiency.

Apart from that, this decrease in efficiency can occur due to problems with various system components, such as the pump, electric motor, and connecting cables between the motor and the power source. Causes can include sub-optimal system design, cavitation, wear, electrical installations that do not meet standards, inappropriate mechanical and electrical operating patterns, and decreased performance of electrical equipment and pumps. Apart from that, imperfect maintenance of mechanical and electrical equipment can also be a contributing factor.

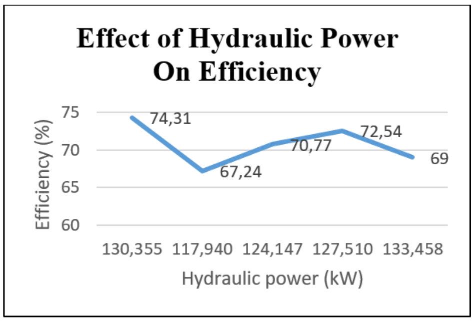

Figure 5. Effect of hydraulic power on efficiency Graph

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Compared with design data, the efficiency of the pump design is 70%. Meanwhile, the efficiency is around 67% to 74% in actual data. The efficiency formula is influenced by the amount of hydraulic power and the power of the driving motor, while the pump head and discharge influence the hydraulic control. If the discharge is more significant, the value of the hydraulic power will be. The greater the hydraulic power, the more efficiency will increase. So, the discharge influences the efficiency value of a pump; if the discharge is higher, then the pump efficiency will also increase. If it is higher, then the pump efficiency will also increase.

5. CONCLUSIONS

The conclusions that can be drawn from the performance analysis of centrifugal pumps, particularly the 946-P-1B pump used for transferring crude oil at PT. The Pertamina International refinery is as follows:

1. The efficiency values for pump 946-P-1-B for January 17-21, 2024, are different daily, namely, 74.31%,67.24%,70.77%,72.54%, and 69%.
2. The efficiency value of the 946-P-1-B pump has different values, but the difference is relatively not too much for each day. The factor that influences pump efficiency is the size of the flow, which can affect the pump's efficiency.
3. A centrifugal pump increases the power of water by creating a pressure difference between the suction and discharge sides through centrifugal force. Based on analysis of the calculation data, it can be concluded that the efficiency of the 946 P-1-B pump ranges between 47% and 56%. Compared with the original pump design data, there has been a significant decrease in pump efficiency due to decreased discharge, which is influenced by the fluid flow density.

REFERENCES

[1] A. Puspawan and B. D. Leonanda, “Analisa Head Losses dan Efisiensi Pompa Sentrifugal Vogel Dari Instalasi Menara Pendingin ke Penampung Utama,” *J. Inersia*, vol. 14, no. 2, pp. 117–125, 2018.

[2] S. Menon, “Centrifugal Pump Analysis,” no. 877, pp. 1–69, 2012.

[3] M. Ferdian, E. M. S. T, J. B. Alam, and S. Alam, “Analisa Pengaruh Frekuensi 40 Hz Terhadap Performa Dan Efisiensi Pompa Sentrifugal Di Pdam Tirta Trubuk Bengkalis,” no. 1, 2023.

[4] L. Xu *et al.*, “Hydraulic Characteristics of Axial Flow Pump Device With Different Guide Vane Inlet Angles,” *Front. Energy Res.*, vol. 10, no. March, pp. 1–13, 2022, doi: 10.3389/fenrg.2022.836456.

[5] M. R. Hidayat, M. Firman, and M. Suprapto, “Analisa Tekanan Dan Efisiensi Pada Pompa Air Sentrifugal Dengan Rangkaian Seri,” *Al-Jazari J. Ilm. Tek. Mesin*, vol. 3, no. 2, pp. 74–77, 2018, doi: 10.31602/al-jazari.v3i2.1621.

[6] I. Michigan and P. Company, “U . S . Nuclear Regulatory Commission Page 2 C0200-08 / dms Attachments NRC Resident Inspector R . Whale , w / o attachment,” 2000.

[7] P. Saksono, “Analisis efisiensi pompa centrifugal pada instalasi pengolahan air kampung damai balikpapan,” *J. Progr. Stud. Tek. Mesin Fakltas Tek. Univ. Balik Papan*, vol. 1, no. 1, pp. 2–10, 2011.

[8] X. Zhang, P. Wang, X. Ruan, Z. Xu, and X. Fu, “Analysis of Pressure Pulsation Induced by Rotor-Stator Interaction in Nuclear Reactor Coolant Pump,” *Shock Vib.*, vol. 2017, 2017, doi: 10.1155/2017/7363627.

[9] U.S. Department Of Energy, “Technical Support Document : Energy Efficiency Program for Consumer Products and Commercial and Industrial Equipment : Automatic Commercial Ice Makers,” no. May, pp. 1–583, 2014, [Online]. Available: https://www.regulations.gov/#!documentDetail;D=EERE-2010-BT-STD-0037-0136.

[10] O. Sepúlveda Steiner *et al.*, “Spatial Variability of Turbulent Mixing From an Underwater Glider in a Large, Deep, Stratified Lake,” *J. Geophys. Res. Ocean.*, vol. 128, no. 6, pp. 1–31, 2023, doi: 10.1029/2022JC018913.

[11] C. N. Wang, F. C. Yang, V. T. T. Nguyen, and N. T. M. Vo, “CFD Analysis and Optimum Design for a Centrifugal Pump Using an Effectively Artificial Intelligent Algorithm,” *Micromachines*, vol. 13, no. 8, 2022, doi: 10.3390/mi13081208.

[12] S. Talib, S. Al, A. G. Mathew, and S. M. Rizwan, “Reliability Modeling and Analysis of a Refinery Based Centrifugal Reliability Modeling and Analysis of a Refinery,” no. July, 2011.

[13] Shivani Kaustubh Chitale, Pranjal Nitin Jadhav, Snehal Suresh Dhoble, and Dr. Mr. Satyajeet Deshmukh, “Parameters Affecting Efficiency of Centrifugal Pump - A Review,” *Int. J. Sci. Res. Sci. Technol.*, pp. 49–58, 2021, doi: 10.32628/ijsrst218573.