High Pressure Transfer Pump Efficiency Calculation Before And After Reverse Engineering at PLTGU XYZ

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ABSTRAK

Pembangkit Listrik Tenaga Gas Uap (PLTGU) merupakan pembangkit listrik yang menggunakan bahan bakar gas dan memanfaatkan kembali gas buang dari turbin gas untuk memanaskan pipa-pipa yang berada di HRSG (*Heat Recovery Steam Generator*) untuk menghasilkan uap dan memutar turbin uap. PLTGU XYZ merupakan Pembangkit Listrik Tenaga Gas dan Uap yang memiliki sebesar 2.154 MW. Salah satu komponen penting yang digunakan pada PLTGU yaitu *high pressure transfer pump*. *High pressure transfer pump* adalah pompa yang berfungsi memindahkan air dari *low pressure drum* melalui *high pressure economizer* menuju ke *high pressure drum*, dengan menggunakan sistem otomatis. Tipe dari *high pressure transfer pump* yang ada di PLTGU XYZ adalah Type MC100-300/9. Untuk menjaga efisiensi pompa *high pressure transfer pump* perlu dilakukan perawatan atau penggantian pada komponen. *high pressure transfer pump* telah dilakukan penggantian komponen pada *shaft* pompa dengan menggunakan metode *reverse engineering.* Sebelum *reverse engineering* pada poros pompa besar efisiensinya adalah sebesar 66 %, dan setelah dilakukan *reverse engineering* pada poros pompa besar efisensinya adalah sebesar 63%, sehingga perbandingan efisiensi pompa sebelum dan sesudah dilakukan *reverse engineering* pada poros pompa adalah sebesar 3%.

Kata kunci : Efisiensi; High Pressure Transfer Pump; Pompa; Reverse Engineering

ABSTRACT

Steam Gas Power Plant (PLTGU) is a power plant that uses gas as fuel and reuses exhaust gas from the gas turbine to heat the pipes in the HRSG (Heat Recovery Steam Generator) to produce steam and rotate the steam turbine. PLTGU XYZ is a Gas and Steam Power Plant which has 2,154 MW. One of the important components used in PLTGU is the high-pressure transfer pump. A high-pressure transfer pump is a pump that functions to move water from the low-pressure drum through the high pressure economizer to the high pressure drum, using an automatic system. The type of high-pressure transfer pump at PLTGU XYZ is Type MC100-300/9. To maintain the efficiency of the high-pressure transfer pump, components need to be maintained or replaced. high pressure transfer pump components have been replaced on the pump shaft using the reverse engineering method. Before reverse engineering the large pump shaft the efficiency was 66%, and after reverse engineering the large pump shaft the efficiency was 63%, so the comparison of pump efficiency before and after reverse engineering the pump shaft was 3%.

Keywords: Efficiency; High Pressure Transfer Pump; Pump; Reverse Engineering

INTRODUCTION

Steam Gas Power Plants (PLTGU) are one of the sources of electrical energy that can contribute to increasing electricity production in Indonesia. The process involves burning natural gas or petroleum in a combustion chamber to generate heat, which then produces steam. The steam is used to drive turbines connected to generators, thus producing electrical energy [1,2]

One example of a PLTGU is PT. PLN Nusantara Power Up Muara Karang, a subsidiary of PT. PLN Persero, which is located in Pluit, North Jakarta. This power plant is capable of producing 2x200 MW of electricity, making a significant contribution to the electricity supply in the area.

In PLTGU, pumps are used for a variety of purposes, including cooling water circulation and fuel pumping, all of which are essential for efficient and reliable power plant operations.

Pumps in PLTGU have an important role in transferring hot water from one component to another, such as from *the High-Pressure Drum* to *the Low-Pressure Drum*. PLTGU Muara Karang uses a multi-level centrifugal type pump to transfer hot water. The pump used here is a multi-level centrifugal pump, with HPTP (*High Pressure transfer pump*) as the name of the pump that operates to transfer hot fluids and generate steam is used as an energy source in the process of generating electrical energy in the Muara Coral generation unit.

PLTGU Muara Karang has carried out *Reverse Engineering* on *the High-Pressure Transfer Pump* (HPTP). *Reverse Engineering* is a process that involves the in-depth analysis and analysis of a product to understand the basic principles of how it works, the materials used, the structure, and the assembly process. This process is carried out through a systematic analysis covering various aspects such as the structure, function, and operation of the product. The goal of *Reverse Engineering* is to identify how a product is made and functions, which can then be used to improve, duplicate, or improve the product.

In the Reverse Engineering process, an in-depth and careful analysis is needed to determine whether the results can produce the best performance of the re-engineered components or systems. It is necessary to perform performance efficiency calculations to ensure that reverse engineering is genuinely successful in restoring and improving performance. This performance efficiency will show how well the component or system functions after going through *the reverse engineering* process compared to before the process was carried out.

(Muji, 2018). Low pump efficiency can be caused by several factors, including suboptimal system design, cavitation, component wear, electrical installations that do not meet standards, improper mechanical and electrical operation, decreased performance of electrical equipment and pumps, and inadequate maintenance of mechanical and electrical equipment.

PLTGU Cycle

At the Gas and Steam Power Plant (PLTGU), there are two cycles that operate simultaneously. The first cycle involves hot air and gas in a gas turbine, known as the Brayton cycle [3]. The second is the water and steam cycle that takes place on the side of the steam turbine, known as the Rankine cycle. The combination of these two cycles is referred to as the *Combined cycle* and is usually depicted in the temperature-enthalpy diagram (T-S diagram). The cycle used in a Gas Power Plant (PLTG) is the Brayton cycle, while the Steam Power Plant (PLTU) operates using the ideal Rankine cycle [4,5].

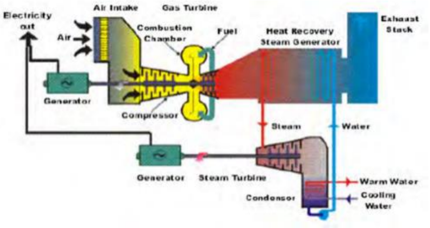

Figure 1 PLTGU cycle

The combination of the gas turbine and steam turbine cycles is achieved through heat transfer equipment in the form of boilers, commonly known as "Heat Recovery Steam Generator" (HRSG). This equipment plays a critical role in the combination cycle, which aims to reuse the heat generated from the gas turbine to improve the system's overall thermal efficiency. In addition to improving thermal efficiency, the application of this combination cycle also contributes to the reduction of air pollution, as this process allows for better utilization of energy and reduces exhaust emissions that have the potential to damage the environment.

Gas Turbines run four stages of the cycle that refer to the Brayton cycle. In this Brayton cycle, there are several processes that occur, namely: [6]

1-2 Compression or compression process on the compressor

2-3 Heat input or input process to the combustion chamber

3-4 Expansion process in the turbine, The process of discharge or discharge of heat in the chimney.

Figure 2 shows the Bryaton cycle for PLTG.

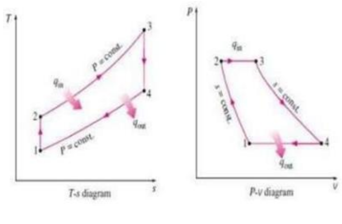

Figure 2 Brayton cycle

In practice, no process is completely perfect, there are always losses that can reduce the power generated by gas turbines. This loss can occur in all three components of the gas turbine system. Therefore, in addition to the ideal Brayton cycle, there is also an actual Brayton cycle as a comparative reference to measure and understand the losses and differences in performance.

Steam power plants (PLTU) and steam turbines operate based on a cyclical process known as the

Rankine cycle. The Rankine cycle is a cycle that involves a phase change between liquid and steam and is the basic principle of a steam power generation system. This cycle describes how water turns into steam, which is then used to power turbines and condenses into water. A simple diagram of the cycle below and the coal-fired power cycle as a whole will illustrate these stages and how these processes contribute to energy generation. Figure 3 shows the Rankine cycle [7,8].

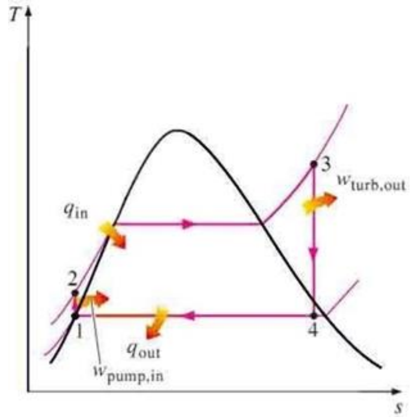

Figure 3 Rankine cycle

Process 1-2: The isentropic compression process occurs when water is pumped into the boiler. The water pressure increases during this process, and the temperature rises slightly.

Process 2-3: At this stage, inside the boiler, the water is heated at a fixed pressure until it turns into hot steam. During this process, the temperature of the vapour increases and its entropy also increases.

Process 3-4: In a turbine, isentropic expansion or vapour adiabatis occurs, where the steam driving the turbine converts thermal energy into mechanical energy that rotates the generator shaft to generate electricity. During this process, the volume of steam increases, while pressure and temperature decrease, while entropy remains stable.

Process 4-1: The condensation occurs in the condenser, where the steam from the turbine is returned to water. This process takes place at constant entropy.

By combining a single cycle of a Gas Power Plant can produce a combination power plant, namely PLTGU, some of the benefits received are:

1. Optimum level of thermal efficiency.
2. Spend on more economical fuel.
3. Fairly short construction.
4. Variations in power capacity.
5. The use of more environmentally friendly fuels.
6. High operational flexibility.
7. The area required is not large.
8. Ease of operation with computerized technology.
9. Efficient start-up time.
10. Maintenance is quite easy with the diagnostic system.

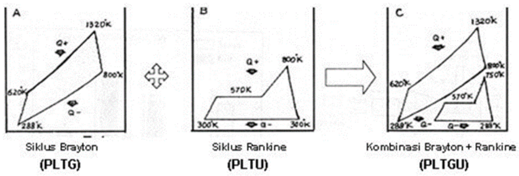

Figure 4 Brayton and Rankine Combined Cycle

Based on the illustration above, it can be seen that the combined cycle used in PLTGU offers better efficiency compared to the cycle applied to PLTG and PLTU. The heat energy generated by the hot gases from the gas turbine is equivalent to the heat energy absorbed by the water to produce steam inside the HRSG.

Centrifugal Pump

A centrifugal pump is a type of kinetic machine that converts mechanical energy into fluid energy through the utilization of centrifugal force. In this pump, the mechanical energy from the drive source is converted into fluid energy through a process that involves a rotating disc and the blades that are in it. The disc is equipped with blades that are designed in such a way that these blades tend to shift the direction of rotation backwards relative to the direction of rotation of the disc. With this design, centrifugal pumps can effectively flow fluids by collecting and increasing kinetic energy in fluids through centrifugal force.

At the Muara Karang PLTGU, the centrifugal pump used is *a High-Pressure transfer pump*, which is specifically designed to meet the needs of the power plant. Here is a picture of the High-Pressure transfer pump:

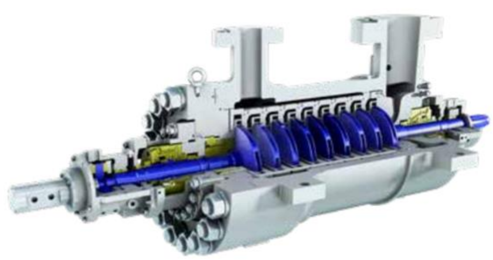

Figure 5 *High Pressure transfer pump*

Here are the parts and parts of High-Pressure transfer pump components [9]:

a. Impellers, play a role in converting the mechanical energy of the pump into velocity energy or kinetic energy in the continuously pumped fluid.

b. The shaft has the main function of transmitting the torque moment from the drive (motor) to the impeller during operation.

c. Volute casing, to reduce the flow speed of fluid entering the pump. Towards the side of the pump outlet, the volute casing is designed to form a funnel that functions to convert kinetic energy into pressure energy by decreasing the flow speed and increasing the pressure. In addition, this design also helps to balance the hydraulic pressure on the pump shaft, thus ensuring stable and efficient operation.

d. Bearings, have the main function of maintaining the position of the rotor relative to the stator, depending on the type of Bearing used. Bearings used on pumps include journal bearings and thrust bearings. Journal Bearings function to withstand heavy forces and other forces that are in the direction of that weight, maintaining the stability of the rotor in relation to the stator. While thrust bearings serve to withstand the axial force generated on the pump shaft, ensuring that the rotor remains in the right position relative to the pump stator. Thus, these two types of Bearings work together to maintain the stability and optimal performance of the pump system.

c. Packing functions to control fluid leakage that may occur in the border area between the rotating pump (shaft) and the stator part.

Reverse Engineering

Reverse Engineering is a method used to identify and understand the underlying technological principles of a device, object, or system by analyzing in detail its structure, function, and operation. This process involves an in-depth examination to outline the components and how the system works, so that it can be determined how the technology works and how it is implemented (Amos, 2008).

Calculation of High pressure transfer pump efficiency

a. Pump Capacity

The equation of continuity results from the application of the law of mass eternity. This law states that under conditions of stationary flow, the mass of fluid flowing through each part in the fluid flow per unit time remains constant. In other words, there is no addition or decrease in the mass of the fluid as it flows through the system. Equation 1 expresses the permanence of mass [10].

$$\dot{m} = Q1.A1 = Q2.A2 = constant \quad (1)$$

Pump capacity refers to the volume of fluid that can be produced by the pump continuously in a given unit of time. The pump capacity is planned based on specific operational needs or can be calculated based on the condition of the piping installation both on the suction side. This capacity is critical to ensure that the piping system and overall operation can run efficiently according to predetermined needs. Here's how to calculate the capacity based on the piping installation on the suction side [10]:

$$Q = \frac{\pi}{4} d_{s^2}.\mathrm{Vs} = \frac{4}{\pi}.d_{d^2}.\mathrm{Vd} = \frac{\dot{m}}{\rho} \quad (2)$$

Information:
Q = Pump Capacity (m^3/s)
ds = MidpointSection of suction (m)
Vs = VelocityA fluid in a suction pipe (m/s)
Vd = Velocity of a fluid in the discharge pipe (m/s)
dd = The middle line of the section in discharge (m)
ṁ = Mass flow rate (kg/s)
ρ = Fluid density (kg/m^3)

b. Head

Head is the energy of each unit of weight with a unit of length. While what is meant by the pumping system head is the total head, which is the difference between the head on the discharge side and the suction side [11].

Head -Suction (Hs)

$$H_s = \frac{Ps}{\rho g} = \frac{Pa}{\rho g} \pm Z_s - hls - \frac{{V_s}^2}{2_g} \quad (3)$$

Information:
H_s= Head -Suction (m)
P_s= suction pressure manometer $({}^{N}/{}_{m^2})$
P_a= atmospheric pressure on the surface of the liquid $()^{N}/{}_{m^2}$
$(+)$ = for the level of fluid above the pump
$(-)$ = for the fluid level below the pump
Z_s= Distance of the surface of the liquid with the Inozzel Suction Pump $()m$
hls = head loss along the suction pipe $()m$
V_s = velocity of fluid in suction pipe (m/s)
ρ = MassAnal Sex $({}^{Kg}/{}_{m^3})$

Head -Discharge (Hd)

$$H_d = \frac{Pd}{\rho g} = \frac{Pa}{\rho g} \pm Z_d - hld - \frac{{V_d}^2}{2_g} \quad (4)$$

Information:
H_d= Head Discharge (m)

P_d = Pressure Discharge Thermometer ($N/_{m^2}$)
P_a= atmospheric pressure, when the closed vessel PA is exchanged for PO is the vapor/gas pressure above the surface of the fluid ($N/_{m^2}$)
(+) = for the fluid level above the pump
(-) = for the level of fluid below the pump
Z_d = Liquid surface distance with pump Discharge nozzle (m)
HLD = Head Loss Along Suction Pipe (M)
V_d = velocity of liquid in discharge pipe (m/s)
ρ = Density of Liquids ($Kg/_{m^3}$)

Head Total Piping System

$$H = H_d - H_s \quad (5)$$

Information:
H_s = *Head Discharge* (m)
H_s = *Head Suction* (m)

c. Pump Power

Pump power is the power that must be provided by the pump's driving engine (motor/turbine) to move fluids. In the case of a 3-phase pump drive motor. For a balanced system, the total power consumed to the load is [12]:

$$Pm = \sqrt{3}\,.V\,.I\,.\cos\varphi \quad (6)$$

Where:

Pm = Pump power (kW)

V = VoltageI (KV)

I = Strong CurrentI(A)

$\cos\varphi$ = power factor

Fluid Power

Fluid power is the pump power that can be used and transferred to the fluid [12].

$$P_f = \frac{\rho.g.H.Q}{1000} \quad (7)$$

Pump Efficiency [10]

$$\eta = \frac{P_f}{p_m}\ 100\% \quad (8)$$

Where:
η = Pump efficiency (%)
p_m= Motor power (kW)
p_f = Fluid Day (kW)

RESEARCH METHODS

Methodology is related to the steps of the method carried out in the research. Figure 6 shows the flow chart as follows:

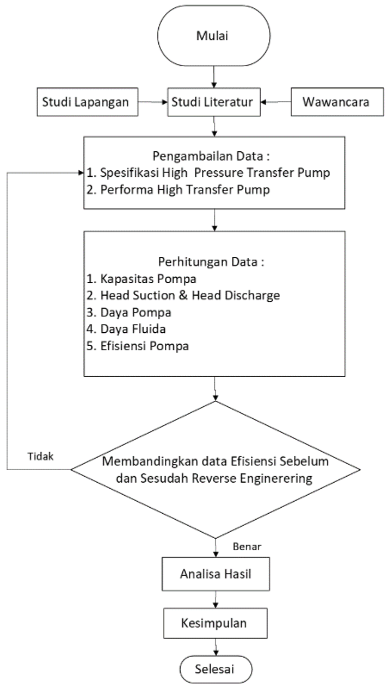

Figure 6 Research Flow Chart

The data analysis used in this study is by comparing the efficiency of *the High Pressure Transfer Pump* before and after *reverse engineering* on the *shaft of the High Pressure Transfer Pump*. Data processing is carried out by calculating pump performance, including:
1. Calculating Pump Capacity (Q)
2.Counting Head (H):
   a. Calculating Head Suction (Hs)
   b. Calculating Head Discharge(Hd)
   c. Calculating the total head on the system (Ht)
3. Calculating the Pump Motor Power (Pm)
4. Calculating Fluid Power (Pf)
5. Calculating Pump Efficiency (η)

The above calculation data was taken on August 9-15, 2021 before *reverse engineering* on the shaft and on April 3,4,22,23,24,25 and April 30, 2024 after *reverse engineering* on the *shaft high pressure transfer pump.*

RESULTS AND DISCUSSION

Transfer pumps at PLTGU there are 2 High Pressure transfer pumps in the process of operating, 1 in the active position and 1 in the standby position. The following are the specifications of the High-Pressure transfer pump as seen in Table 1.

Table 1 Specification of High-Pressure transfer pump

Manufacturer	SULZER WEISE
Type	MC 100-300/9
Serial	94320
Number Of Stages	9
Liquid	Boiler Water
Suction Temperature	159°C
Debit*(m^3/h)*	191,46
Head (m)	1242
NPSH(m)	5 *m*
NPSH avail	12 *m*
Speed (rpm)	2980
Daya (Kw)	753
Kapasitas *(m^3/h)*	188,66
Motor	
Manufacturer	ELIN
Type	HKW W -145 CO2 ESC – 06 M
Serial	52531095001
Daya	900 kW
Speed	2976 rpm
Vod – amp – az	Y 6000 V – 101 – 50HZ

Table 2 is the average result data on performance test data taken on August 9-15, 2021 before reverse engineering on the shaft and on April 3, 4, 22, 23, 24, 25 and 30, 2024 after *reverse engineering* on the shaft high pressure transfer pump.

Table 2 Average Data *Performance Test High Pressure transfer pump*

High Pressure transfer pump Unit 1									
No	Waktu	Arus (A)	*Mass Flow* (T/h)	Temperatur *Inlet* (°C)	Temperatur *Outlet* (°C)	*Pressure Suction* (bar)	*Pressure Discharge* (bar)	*Feedwater Density* Kg/m^3	Tegangan Motor Pompa (kW)
1	9 Agustus 2021 (Sebelum *Reverse*)	72,7	124,4	159	171,5	6,83	116,2	903,15	6
2	3 April 2024 (Setelah *Reverse*)	71,5	119,3	159,4	171,8	6,88	115,6	902,86	6

Table 3 is the result of calculation of pump capacity, *suction head*, *discharge head*, total head, motor power, fluid power, and pump efficiency, the pump calculation data is taken from the average performance test data taken on August 9-15, 2021 before *reverse engineering* on the shaft and on April 3,4,22,23,24,25 and April 30, 2024 after *reverse engineering* on the shaft high pressure transfer pump.

Table 3 Efficiency Calculation Results *of High Pressure Transfer Pump* Unit 1

High Pressure transfer pump Unit 1										
No	Waktu	Q *(m^3/s)*	*Hs* (m)	*Hd* (m)	*Htotal* (m)	Pm (kW)	Pf (kW)	V (kW)	I (A)	η (%)
1	9 Agustus 2021 (Sebelum Reverse)	0,0381996	77,11523	1342,4598	1234,8598	636,00906	417,788926	6	72,7	66
2	3 April 2024 (Setelah Reverse)	0,0366613	77,70471	1305,6198	1227,9150	631,59233	398,581636	6	71,5	63

From Figure 7 is a graph of the calculation data obtained based on the performance data of the High-Pressure transfer pump before and after Reverse Engineering on the PLTGU shaft.

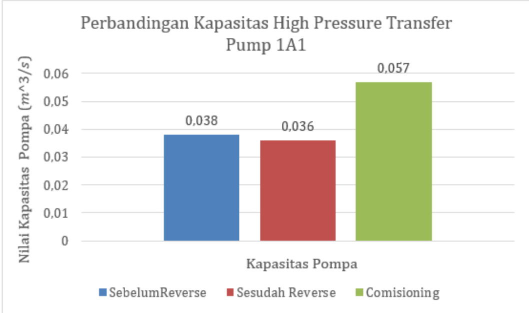

Figure 7 High *Pressure Transfer Pump Capacity Chart*

In the graph above, we can clearly see the comparison of the capacity of the high pressure transfer pump has decreased, we can see that before *reverse engineering*, the value of the capacity of the high pressure transfer pump before *reverse engineering* is as large as then after 0,0381 m^3/s *the reverse engineering* activities are carried out In the pump shaft component, there is a decrease in capacity due to the calculation of the pump capacity after reverse engineering. We can find out the cause/factor of the decrease in capacity in 0,0015 m^3/s 0,0366 m^3/s *the high pressure transfer pump* due to the less than optimal *reverse engineering process*, namely from the distance between impellers which is less precise when installed on the shaft, as a result of which the discharge of incoming water flow is not optimal and has an effect on the performance *of the high pressure transfer pump* to decrease.

In Figure 8 is a graph of the Head that we can see from the calculation results, before and after *Reverse Engineering* on the shaft.

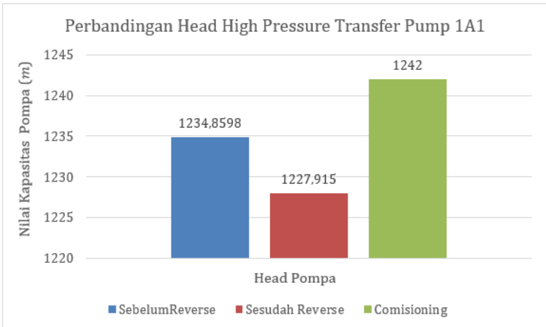

Figure 8 Graph *Head High Pressure transfer pump*

In Figure 8 we can clearly see the comparison of the pump head has decreased, we can see that before reverse engineering, the value of the pump head high pressure transfer pump before *reverse engineering* is then after 1234,8598 *m reverse engineering activities are carried out* on the pump shaft components, there is a decrease in the head by *6.9m* Because the calculation results from the pump head after reverse engineering are *1227.9150 m*. We can find out the cause/factor of the decrease in the pump head due to leaks in the pump and long operating hours, less than optimal maintenance that is only carried out when in breakdown conditions, leaks in the pump, and pump components that are old enough, all of which contribute to a decrease in pump performance. The supply of less than optimal lubricating oil also has an impact on the lubrication system, causing erosion and rust in pump components and impacting the high pressure transfer pump head.

In Figure 9 is the graph above we can see the results of the calculation, the data of the calculation results obtained based on the performance data of the High Pressure transfer pump before and after Reverse Engineering on the shaft.

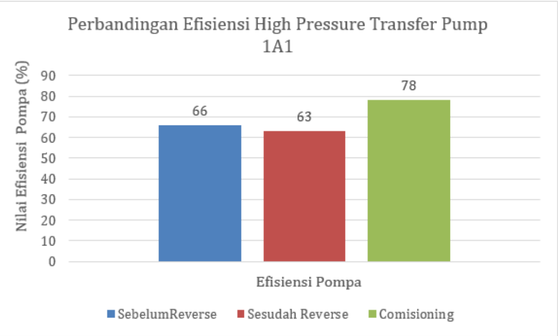

Figure 9 High *Pressure Transfer Pump Efficiency Graph*

In Figure 9 is a graph that we can clearly see the comparison of pump efficiency has decreased, we can see that before reverse engineering, the value of the efficiency of the high pressure transfer pump before reverse engineering is 66% then after reverse engineering activities are carried out on the pump shaft components, there is a decrease in efficiency by 3% because the calculation results of the pump efficiency after reverse engineering are 63%. The cause of the decrease in efficiency in the pump is damage to the Impeller components that have been repaired after cavitation, then reassembled with the reversed rotor part, namely the Shaft. The method used when repairing a damaged impeller is by the build up method (welding), not the replacement of new components. Data shows that the installation of the repaired impeller with the Shaft that has been carried out by Reverse Engineering causes a decrease in the performance of the High Pressure transfer pump Unit 1 by 3%. To increase efficiency and prevent damage to the pump, it is necessary to maintain the pump shaft and impeller as components that play an important role in high pressure transfer pumps.

CONCLUSION

Based on the calculation results of the pump data before *the Reverse Engineering activity, the* value of the efficiency produced by the High Pressure Transfer Pump is 66% and after Reverse Engineering is carried out on the High Pressure Transfer Pump shaft, the efficiency value decreases by 3%, because the efficiency value after Reverse Engineering is 63%. Some of the factors or causes of the decrease in efficiency of the High Pressure Transfer Pump are from long enough operating hours and the age of the pump, leaks in the pump, materials from pump components that are old enough, replacement materials that do not meet factory standards, repair methods that do not meet standards, namely repair impellers with welding methods, and pumps that have stopped operating for 2 years, and the last is that the Reverse Engineering process is not exactly what it is, resulting in less than optimal pump performance and the efficiency of the pump to decrease.

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