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# Experimental Study on Evaluation of Cavitation and Working Performance of Moswell Aqua 175 Centrifugal Pump on Series Series with Debit Variations

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**ABSTRACT**

Centrifugal pump is commonly used in industry. Centrifugal pumps work by converting mechanical energy into pressure and kinetic energy. In centrifugal pumps, cavitation or decrease in pump performance due to bubbles in the pump cavity is possible. The impact of cavitation is possibly damage the impeller, reduce efficiency, and increase maintenance costs. In this study, the evaluation of cavitation and the calculation of pump and head efficiency are important things to be carried out in assessing the performance of the pumping system. The pump used in this study is a Moswell Aqua 175 centrifugal pump. The piping systems are arranged in series. The variable used is flow discharge with 10 variations. The maximum flow discharge of the Moswell Aqua 175 pump is 60.7 L/min as the highest variation and the lowest variation is 9.4 L/min. The research began by compiling a series of piping systems and then draining water on the pump by varying the discharge of water flow. The calculation in this study is to find the NPSH-A (Net Positive Suction Head – Available) value, head, and pump efficiency. The results of the study showed that the NPSH-A value was above 8m and greater than the NPSH-R (Net Positive Suction Head – Required) value of 3m which means cavitation did not occur in the pump. The head value and efficiency of the pump increase significantly as the flow discharge variation increases. At the highest water discharge, which is 60.7 L/min, a head value of 9.677m was obtained with a pump efficiency of 37.93%. This shows that centrifugal pumps work more efficiently at higher flow rates.

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## INTRODUCTION

Pumps are vital devices that function to drain liquids, especially water. Pumps work by moving fluids from one location to another through a piping system, which causes pressure changes in the fluid on a continuous basis. Generally, pumps are used to drain fluids. The working principle of the pump creates a pressure difference between the suction side (suction) and the discharge side (Puspawan & Leonanda, 2018). Pump performance is affected by head, capacity, and efficiency. Head is the pump's ability to lift fluids, capacity refers to the volume of fluid moved or flowed in units of time, while efficiency is the ratio between the power generated by the pump and the energy required by the drive motor to run it (Mustakim, 2015).

In the piping installation system, the phenomenon of cavitation is often not noticed, while cavitation causes a loss impact in the piping installation system. Cavitation is the process of forming empty cavities in a liquid that then explode suddenly. Cavitation occurs when the fluid is in an area with rapid pressure changes. This phenomenon is very dangerous because it can damage important components in the pump and reduce its performance. In the case of cavitation, the part of the pump that is most often affected is the suction side. This is due to the suction pressure being too low, even under saturated steam pressure. Cavitation can occur when the pressure in a piping system or pump drops below the pressure of saturated steam at a certain operating temperature (Kamiel et al., 2019).

If cavitation is not observed, it will result in noise and an increase in vibration level due to the explosion of bubbles that burst in the pump (Wijianto & Effendy, 2015). Damage to the pump can occur due to various factors, such as leakage due to damaged seals, wear on gears, damage to the blade, and bent shafts (Fakhruddin, 2020). In the use of centrifugal pumps, it is important to be aware of the possibility of cavitation, which can lead to a decrease in pump capacity as well as damage to the impeller and cause vibration.

In addition to cavitation, to ensure that the centrifugal pump is still functioning optimally, it is necessary to calculate the efficiency of the pump. An inefficient pump will waste energy while moving fluids in the system, ultimately increasing the cost of electricity for its operation (Muji et al., 2018). The calculation of the efficiency of the pump will determine the performance of the pump. The impact of cavitation if it occurs is that it can damage the impeller, reduce efficiency, and increase maintenance costs. To prevent cavitation from occurring, the NPSH-A value must be greater than NPSH-R which means the pump must have more energy or head available on its inlet side compared to the energy required for fluid transfer (Wijianto & Effendy, 2015). While efficiency in percentage units (%) is the comparison between power from water (hydraulic power) and power from pump motors or pump drives (power engines).

Various studies have been conducted to determine the effect of flow discharge variations on pump performance, such as research that has been conducted by Ratnawati, et al in 2022, namely about the effect of flow discharge variations on the performance of single stage grundfos ns basic 4-23m centrifugal water pumps with optimal efficiency results of 292.087% at 0.0010 $m^3/s$ discharge variations (Ratnawati et al., 2022). Regarding previous research, no one has used the moswell aqua 175 type centrifugal pump which is arranged in a series with variations in flow discharge. This research aims to determine the cavitation, work efficiency, pump head, and working performance of centrifugal pumps.

## METHOD

The research carried out was the evaluation of pump cavitation and the calculation of efficiency in centrifugal pumps. The pump used in this test is a Moswell Aqua-175 centrifugal pump with a series that is arranged independently, with a power specification of 0.75 kW, a maximum discharge of 100 liters/minute and an engine speed of 2850 rpm, at a voltage of 220 V. This pump has a suction and discharge pipe diametre of 1" and a type of PVC pipe AW 1" and has a head by 13.5 m and NPSH-R value of 3. The measuring tools used in this study are pressure gauge, flowmetre, and clamp metre. The variables used in this study are flow discharge with 10 discharge variations starting with the lowest discharge variation of 9.4 L/min and the highest discharge variation of 60.7 L/min. The maximum flow discharge in the Moswell Aqua-175 type centrifugal pump is 60.7 L/min. The following is the installation scheme of the centrifugal pump series in this study.

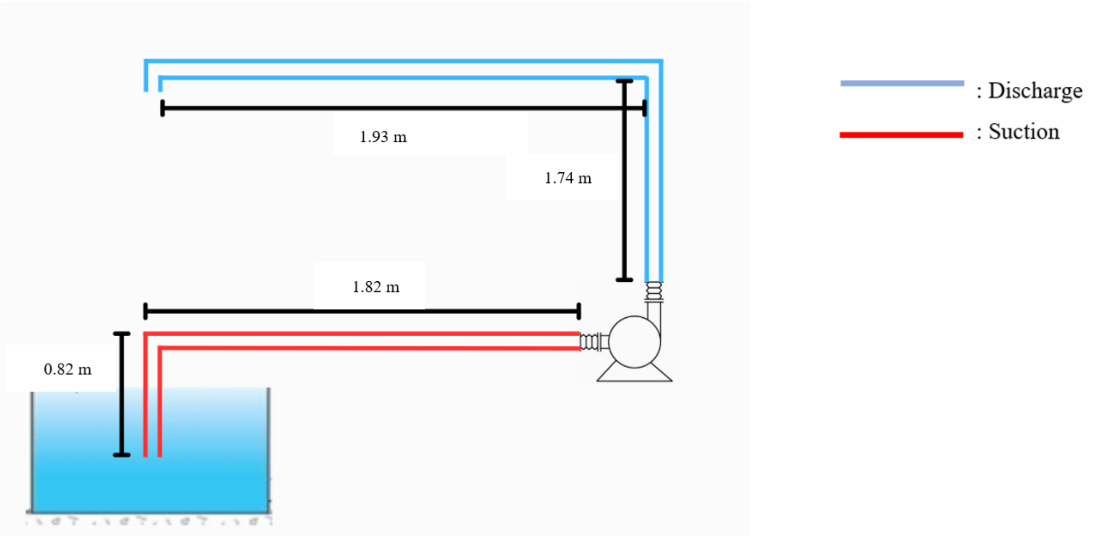


Figure 1. Pump Series Installation Scheme

In this reseacrh, the calculation of the head value and pump efficiency was carried out to determine the working performance of the pump. The calculation steps in this study are as follows:

### Mayor Losses

Major losses are losses in piping systems that occur due to friction between the fluid and the pipe wall along the flow (Kurniawan, 2018). The major losses is shown by equation 1.

$$\text{Hf} = f\,\frac{L.V^2}{D.2\,g} \tag{1}$$

Where:

f = Pipe friction coefficient (without unit)

L = Pipe Length (m)

D = Pipe inner diametre (m)

V = Average flow velocity (m/sec)

g = Acceleration of gravity (m/$sec^2$)

Then the value of V is obtained from the equation 2.

$$V = \frac{Q}{A} \quad (2)$$

Where:

Q = Flow/discharge capacity ($m^3$/sec)

A = Pipe Cross Section Area ($m^2$)

Then the value of A is obtained from the equation 3.

$$A = \frac{\pi D^2}{4} \quad (3)$$

At Re < 2300 flows are laminar, Re > 4000 flows are turbulent, Re = 2300 – 4000 flows are transitional. In the laminar the coefficient for the pipe (f) can be calculated by equation 4.

$$f = \frac{64}{Re} \quad (4)$$

To calculate the friction loss in turbulent flow of a pipeline can use the Darcy equation in equation 5.

$$f = \frac{0.0005}{D} \quad (5)$$

**Minor Losses**

Minor losses are losses in the piping system caused by the presence of connections or changes in the shape of the pipe (Rosmiati et al., 2019). The calculation of the value of minor losses uses the equation 6.

$$Hf = f\frac{V^2}{2\,g} \quad (6)$$

Where:

*f* = Pipe friction coefficient (without unit)

*f* can be searched on the diagram or the equivalent of lenght (equivalent length)

V = Average flow velocity (m/sec)

g = Acceleration of gravity (m/sec$^2$)

**Net Positive Suction Head Available (NPSH-A)**

NPSH-A is a measure of the absolute pressure that occurs at the incoming suction port of a particular pump. The NPSH-A value is calculated using the equation 7.

$$NPSH - A = \frac{P_a}{\gamma} - \frac{P_v}{\gamma} - h_s - h_{ls} \quad (7)$$

Where:

$P_a$= Pressure (1 atm)

$P_v$= Saturated steam pressure

$h_s$= Static suction height

$h_{ls}$= *Head* loss total (*suction*)

$\gamma$= Water density

**Head Pump**

The Pump Head is the maximum height that the pump can reach to pump against pressure. The pump head can be calculated using the equation 8.

$$H = H_d - H_s + H_a \tag{8}$$

Where:

$H_d$ = The pressure at the disharge (m), which can be calculated using equation 9

$H_s$ = Pressure on suction (m), which can be calculated using equation 10

$H_a$ = Suction and discharge height difference (m)

$$H_d = \frac{P_{discharge}}{\rho \times g} \tag{9}$$

Where:

$P_{discharge}$ = Discharge pressure (Pascals)

$\rho$ = Water density

g = Acceleration of gravity (m/sec$^2$)

$$H_s = \frac{P_{suction}}{\rho \times g} \tag{10}$$

Where:

$P_{suction}$= Pressure Suction (pascal)

$\rho$ = Water density

g = Acceleration of gravity (m/sec$^2$)

**Pump Efficiency**

Pump efficiency is calculated to find out how efficient the pump is in working. Pump efficiency can be calculated using the equation 11

$$\eta_{pt} = \frac{P_h}{P_{in}} \times 100\% \tag{11}$$

Where:

$P_h$= Hydraulic Power (kW), can be calculated by equation 12

$P_{in}$= Shaft power (kW), can be calculated by equation 13

$$P_h = \frac{\rho \times g \times Q \times H}{1000} \tag{12}$$

Where:

$\rho$ = Water density ($^{kg}/_{m^3}$)

$g$ = Gravitation ($^{m}/_{s^2}$)

$Q$ = Discharge ($^{m^3}/_{s}$)

$H$ = Head Pump (m)

$$P_{in} = N \times Cos\theta \quad (13)$$

$$N = \frac{V_{Ukur} \times I_{Ukur}}{V_{Spesifikasi} \times I_{Spesifikasi}} \quad (14)$$

Where:

$V_{Measured}$ = Voltage measured (volt)

$V_{Specification}$ = Voltage at pump specification (volt)

$I_{Measured}$ = Measured current (ampere)

$I_{Specification}$ = Current at pump specifications (ampere)

## RESULTS AND DISCUSSION

The performance of a centrifugal pump is shown in a working characteristics curve that includes cavitation, the pump head, and the efficiency obtained from the pump power.

### Cavitation

Cavitation evaluation is carried out on centrifugal pumps based on the comparison between NPSH-A (Net Positive Suction Head Available) and NPSH-R (Net Positive Suction Head Required) values. Cavitation occurs when NPSH-A is lower than NPSH-R, which leads to the formation of steam bubbles on the suction side of the pump, and can damage the pump and reduce its operating efficiency. Table 1 shows the NPSH-A values measured at various flow discharges in liters per minute (L/min).

Table 1. NPSH-A value on flow debit variation

| Debit | Pa (atm) | Pv (kg/cm$^2$) | $\gamma$ (kg/m2) | hs (m) | hls (m) | NPSH-A (m) |
|---|---|---|---|---|---|---|
| 9.40 | 1.033 | 0.3359 | 1000 | 0.61 | 0.0268 | 9.3572 |
| 13.60 | 1.033 | 0.3359 | 1000 | 0.61 | 0.0561 | 9.3279 |
| 19.60 | 1.033 | 0.3359 | 1000 | 0.61 | 0.1165 | 9.2675 |
| 26.90 | 1.033 | 0.3359 | 1000 | 0.61 | 0.2195 | 9.1645 |
| 33.10 | 1.033 | 0.3359 | 1000 | 0.61 | 0.3323 | 9.0517 |
| 38.50 | 1.033 | 0.3359 | 1000 | 0.61 | 0.4496 | 8.9345 |
| 42.20 | 1.033 | 0.3359 | 1000 | 0.61 | 0.5401 | 8.8439 |
| 48.20 | 1.033 | 0.3359 | 1000 | 0.61 | 0.7046 | 8.6794 |
| 54.00 | 1.033 | 0.3359 | 1000 | 0.61 | 0.8844 | 8.4996 |
| 60.70 | 1.033 | 0.3359 | 1000 | 0.61 | 1.1175 | 8.2665 |

Based on Table 4.1 the NPSH-A value has decreased along with the increase in water discharge. This is a common phenomenon, where the increase in discharge causes an increase in the fluid flow rate which at each discharge reduces the pressure on the suction side of the pump. Cavitation has the potential to occur if NPSH-A falls below NPSH-R. In this case, the lowest NPSH-A value is 8.2665 m at a discharge of 60.7 L/min, which is still well above the NPSH-R value of 3 m that the tested centrifugal pump operates safely within the given discharge range. The NPSH-A value obtained is always higher than the required NPSH-R, which means that the pump has sufficient pressure reserve to prevent cavitation from occurring.

**Head Pump**

This head is the height difference between the water level on the outlet side and the suction side; a positive (+) sign is used when the water level on the outward side is higher than the suction side. value $H_d$ is the pressure on the discharge divided by the specific type time and $H_s$ pressure on suction, $\Delta H$ obtained from $H_d$ - $H_s$ then $H_p$ is the sum of $\Delta H$ and the height of the suction face to the pump. The relationship between the variation in flow discharge and the value of the head pump is shown in figure 1.

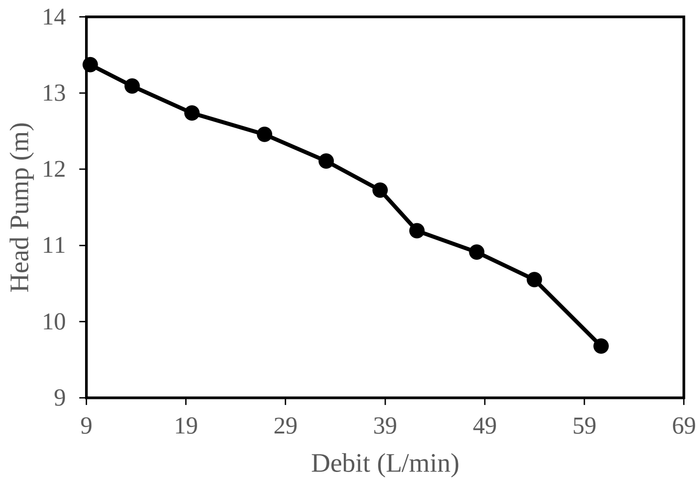


Figure 2. relationship between the variation in flow debit and the value of the head pump

Based on figure 1, the higher the discharge, the lower *the head* so that the better the performance of the centrifugal pump. The lowest discharge variation of 9.4 L/min resulted in *a head* value of 13.3714 m and continued to decrease until the highest discharge variation was 60.7 L/min with a head value of 9.6771 m. The discharge value was inversely proportional to the head value produced; this was due to the characteristics of centrifugal pumps. When the discharge is low, it means that less fluid is pumped. The energy normally used to increase the pressure (*head*) is now divided to move a larger volume of fluid, so the resulting head decreases (Safitri, 2018).

**Efficiency**

The efficiency of the ηp pump is the change of the pump shaft power (Whp) to the hydraulic power of the pump (Wsh). Hydraulic power or water power is the power produced by the flow of fluids, usually water, through a system such as turbines, pumps, or pipes. In addition to hydraulic power, to determine the efficiency value, shaft power is also needed which is the amount of mechanical energy needed to rotate the pump shaft. The relationship between the variation in flow discharge and the efficiency of the pump is shown in Figure 2.

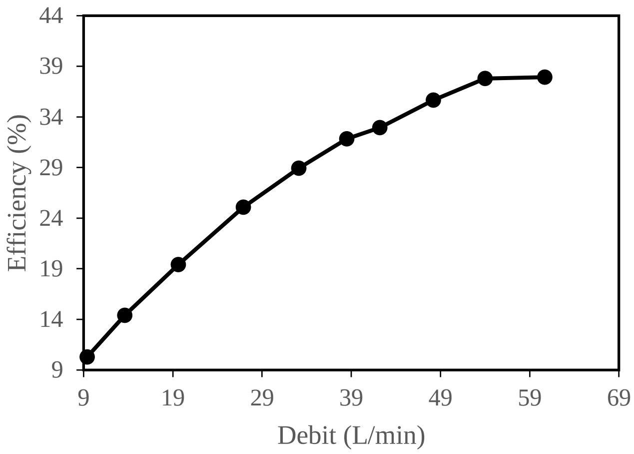


Figure 3. relationship between the variation in flow debit and the value of the efficiency pump

Based on figure 2, the higher the discharge, the higher the water power value (Whp) and pump shaft power (Wsh) so that the pump efficiency value also increases. At the lowest discharge, which is 9.4 L/min, the Whp value is 0.0206 kW and Wsh is 0.1996 kW with a pump efficiency value of 10.29%. There was an increase in efficiency value until the highest discharge variation of 60.70 L/min was obtained with a value of Whp 0.0960 kW and Wsh 0.2532 kW with a pump efficiency value of 37.93%. This increase in efficiency shows that under certain conditions, the pump works more optimally by converting more shaft power into water power. The data that has been analyzed shows a linear relationship between Whp and Wsh, as well as an increase in pump efficiency along with an increase in water power and shaft power. The significant increase in pump efficiency initially indicates that the system works more efficiently in converting mechanical energy into fluid energy.

**Evaluation of Pump Performance**

Pump performance evaluation is the process of assessing how well a pump is performing in meeting its operational needs. The working characteristics curve of a centrifugal pump includes the relationship between discharge (L/min) and two main parametres, namely *head* (metre) and pump efficiency (%). The performance characteristic curve of the centrifugal pump in this study is shown in Figure 3.

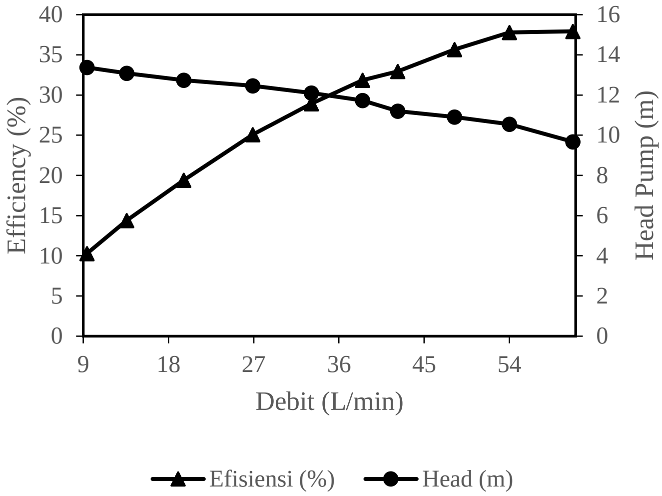


Figure 4. The performance characteristic curve of the centrifugal pump

Based on figure 3 The working performance of the pump can be analyzed by the relationship between discharge and head and efficiency which shows the general characteristics of centrifugal pumps, where *the head* decreases as the discharge increases and the efficiency increases. At a discharge of 54 L/min up to a maximum discharge variation of 60.4 L/min, the increase in efficiency begins to slow down indicating that the pump is approaching its optimum efficiency limit. Lowering the head with increased discharge is a common characteristic of centrifugal pumps, where the pump has to work harder to move a larger amount of fluid, resulting in less pressure. This is in accordance with research conducted by Safitri in 2018 on an experimental study of the characteristics of single stage centrifugal pumps and cussons friction loss apparatus with the results of higher the discharge, the lower the head value, namely the size of the pump head at a flow capacity of 0.l/min is 22.7 m and continues to decrease gradually until a cellphone of 18.6 m is obtained at Q of 60.l/min (Safitri, 2018).

From the evaluation of the characteristic curve in Figure 3, it is shown that this centrifugal pump shows optimal performance at higher discharges, both from the *head* and efficiency. These pumps may be less efficient at low discharges, where *the head* and efficiency are both lower. Therefore, it is important to operate this pump to regulate the water discharge close to the recommended maximum discharge to achieve high efficiency.

## CONCLUSION

Based on the results of the research that has been carried out, it can be concluded that the centrifugal pump series of this study does not indicate cavitation because the NPSH-A value is greater than the NPSH-R value. The research data shows that as the water discharge increases, the head value and efficiency of the centrifugal pump also increase significantly. This suggests that centrifugal pumps work more efficiently at higher flow rates, but must be balanced against the risk of cavitation as the NPSH-A value decreases. The results of the data analysis show that the pump is most efficient and effective at higher flow rates but requires proper operating conditions to avoid damage to centrifugal pumps due to cavitation.

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