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Book of Abstracts

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BOOK OF ABSTRACTS

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Experimental Study on the Impact of Impeller Blade Length and Input Voltage Variations on the Performance of a Single-Stage Peripheral Pump

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CONTEXT

Peripheral pump manufacturers are in fierce competition to design pumps capable of achieving high heads to meet consumer demands. These pumps are essential for applications in companies, hotels, and multi-storey apartments that require efficient water supply at significant heights.

PURPOSE OR GOAL

This study aimed to analyse the effect of impeller blade length variations and input electrical voltage on the head and efficiency of peripheral pumps.

DESIGN/APPROACH OR METHODOLOGY/METHODS

The research tested impeller blade lengths of 8 mm (standard), 9 mm, 10 mm, and 11.5 mm, with input electrical voltages of 200 V, 210 V, 220 V, 230 V, and 240 V. The test was conducted on a single pump with a pipe diameter of ¾ inch. Data collected included pressure, discharge, electrical voltage, electric current, and calculations of head values, waterpower, motor power, and pump efficiency.

FINDINGS: ACTUAL OR ANTICIPATED OUTCOMES

The findings indicate that increasing input electrical voltage resulted in higher discharge and head but reduced pump efficiency. At an input voltage of 240 V, the blade length of 8 mm achieved a discharge of 30.10 lpm, a head of 6.13 m, and an efficiency of 12.27%. The 10 mm blade length produced a discharge of 29.80 lpm, a head of 6.23 m, and an efficiency of 12.17%, showcasing optimal performance. However, the blade length of 11.5 mm reduced head to 5.82 m and efficiency to 11.42%.

CONCLUSIONS/RECOMMENDATIONS

This study concludes that impeller blade length and input electrical voltage significantly influence the head and efficiency of peripheral pumps. A balance between these variables is critical to achieving optimal pump performance for high-head applications.

KEYWORDS

Peripheral pump, impeller blade, input electrical voltage, head, efficiency.

PAPER TYPE

Original Research

EXPERIMENTAL STUDY OF THE EFFECT OF VARIATIONS IN IMPELLER BLADE LENGTH AND INPUT ELECTRICAL VOLTAGE ON THE PERFORMANCE OF A SINGLE-COMPANIED PERIPHERAL PUMP

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Abstract. Pump companies, especially peripheral pumps, compete in designing pumps to get high heads following consumer desires in using pumps, such as companies, hotels or multi-storey apartments that require pumps with high heads to supply water at the required height. The purpose of this study was to analyze the effect of variations in the length of the impeller blade and input electrical voltage on the head and efficiency of peripheral pumps. The variations tested included impeller blade lengths of 8 mm (standard), 9 mm, 10 mm, and 11.5 mm, and input electrical voltages of 200 Volts, 210 Volts, 220 Volts, 230 Volts, and 240 Volts. The test was carried out using a single pump with a pipe diameter of ¾ inch, where the data obtained included pressure, discharge, electrical voltage, electric current, and calculations of head values, water power, motor power, and pump efficiency. The results showed that the greater the input electrical voltage, the greater the discharge and head, but decreased the pump efficiency. At 240 Volts of electric voltage, the impeller blade length of 8 mm produces a discharge of 30.10 lpm, a head of 6.13 m, and an efficiency of 12.27%. For a blade length of 9 mm, the discharge value is 29.91 lpm, a head of 6.19 m, and an efficiency of 12.06%. A blade length of 10 mm produces a discharge of 29.80 lpm, a head of 6.23 m, and an efficiency of 12.17%. While at a blade length of 11.5 mm, the discharge value is recorded at 29.95 lpm, a head of 5.82 m, and an efficiency of 11.42%.

Keywords: Peripheral Pump, Impeller, Input Electric Voltage, Head, Efficiency.

1. Introduction

A pump is a tool for moving fluids from one place to another that works on the basis of converting mechanical energy into kinetic energy [1]. Pumps have various forms and are classified according to how they work, one of which is a regenerative or peripheral pump. A peripheral pump is a type of kinetic pump with characteristics that can produce high heads at low flow rates [2]. Therefore, the use of peripheral pumps is widely used in households [3] to companies for the provision of clean water [4].

Of course, every pump company, especially peripheral pumps, competes in designing pumps to get high heads according to consumer desires in using pumps, such as companies, hotels or multi-storey apartments that require pumps with high heads to be able to supply water at the required height [5]. To be able to produce a peripheral pump with a higher head, it can be done by making a different Impeller.

Therefore, this study will examine experimentally by adding different Impeller blade lengths so that it is expected to increase the head on the peripheral pump. And variations in the input electrical voltage on the pump will also be carried out which will later be useful for finding out at what input electrical voltage the pump will work ideally. The calculations carried out reach the calculation of peripheral pump performance so that the influence of increasing the head on the efficiency of the peripheral pump can be seen.

2. The Basic Theory

2.1 Pump

A pump is a tool that functions to move fluids (water) from one place to another by increasing the pressure on the fluid (water) [11]. In addition, for fluid installation purposes, pumps are also often used to transfer fluids, either in the form of clear water or oil from one place to another. Pumps can be classified or categorized based on the mechanism of the function of moving pressurized liquids from the contour of a place with a lower surface to a higher surface by increasing pressure and increasing speed. Factors that need to be considered in selecting a pump are the fluid and the rating (debit and head) required [12].

2.2 Peripheral Pump

Peripheral pumps are a combination of centrifugal pumps and positive displacement pumps[13]. These pumps combine the high outlet pressure of a displacement pump and the flexible operation of a centrifugal pump[14]. The impeller on a peripheral pump looks very different from a centrifugal impeller. The impeller has radially oriented buckets or teeth, which makes the impeller look more like a turbine rotor, hence the name turbine pump. These pumps are also referred to as vortex, fringe, or regenerative pumps[15].

2.3 Working Principle of Peripheral Pump

In a peripheral pump, there are two rows of vanes on either side of the impeller edge, these vanes rotate in a channel. The fluid flows in at the suction end and is taken up by the impeller. After making almost one revolution in the annular channel, the fluid has a high velocity which is expelled out (discharge). In a peripheral pump, the fluid circulates between the impeller vanes. Due to this action, the fluid flows in a helical path as it is carried forward. As a result, energy is added to the fluid in a regenerative motion by the impeller vanes as it moves from suction to discharge. This regenerative action has the same effect as the multistage in a centrifugal pump. In a multistage centrifuge, the fluid pressure is the result of the energy added in the various stages. Similarly, in a peripheral pump, the pressure at the discharge is the result of the energy added to the fluid by a number of impeller vanes[16]. The working principle of a peripheral pump can be seen in Figure 1.

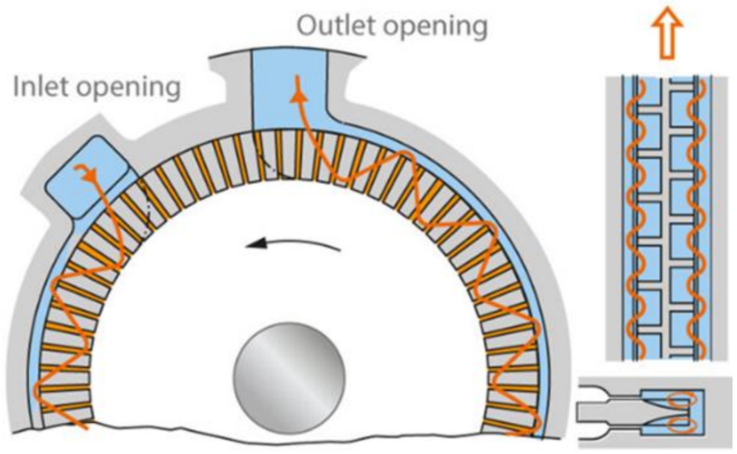

Figure 1. Working principle of peripheral pump

Recirculation of fluid between the peripheral vanes occurs several times between suction and discharge. The path of fluid movement can be likened to an elongated helical spring bent into a circle until its ends almost touch. When the pump operates at low head, the distance between the helical coils increases. At high head, the helix closes. This means that the fluid circulates more on its way from suction to discharge[17].

2.3 Peripheral pump calculation parameters

The calculation parameters used in this study include pump head H_P (m), water power P_w (Watt), motor power P_M (Watt) and pump efficiency η_{pompa} (%) which can be seen as follows:

2.3.1 *Pump Head H_P (m)*

The pump head equation is:

$$\mathbf{H_P = \frac{P_d - P_s}{\rho_{water}\, g}} \quad \textbf{(2.1)}$$

Information: H_P = Pump head (m), P_d = Discharge pressure (m), P_s = Suction pressure (m), ρ_{water} = Density ($\frac{kg}{m^3}$), g = Earth's Gravitational Acceleration ($\frac{m}{s^2}$).

2.3.2 Continuity equation

The continuity equation is:

$$\mathbf{Q_{water} = \frac{V}{A}} \quad \textbf{(2.2)}$$

To find the fluid velocity using the equation:

$$\mathbf{V = \frac{Q_{water}}{A}}$$

Information: Q_{water} = Fluid flow rate ($\frac{m^3}{s}$), V = Fluid velocity, both for suction and discharge side ($\frac{m}{s}$), A = Pipe cross-sectional area (m^2).

2.3.3 Water Power P_w (Watt)

The water power equation is:

$$\mathbf{P_w = \rho_{water}\, g\, Q_{water}\, H_P} \quad \textbf{(2.3)}$$

Information: P_w = Water power (kW), ρ_{water} = Water density ($\frac{kg}{m^3}$), g_{earth} = Earth's gravitational acceleration ($\frac{m}{S^2}$), Q_{water} = Water discharge ($\frac{m^3}{s}$), H_P = Pump head (m).

2.3.4 Motor Power P_M (Watt)

The motor power equation is:

$$\mathbf{P_M = V_{in}\, I \cos\theta} \quad \textbf{(2.4)}$$

Information: V_{in} = Voltage or input electric voltage (Volt). I = Electric current (Ampere). θ = Phase angle between voltage and current.

2.3.5 Pump Efficiency η_{pump} (%)

Pump efficiency is a statement related to the performance of a pump with a percentage unit (%) which is a comparison of energy from water (water power) to energy from the pump motor or pump drive (motor power). The pump efficiency equation is:

$$\mathbf{\eta_{pompa} = \frac{P_w}{P_M} \times 100\%} \quad \textbf{(2.5)}$$

Information: η_{pump} = Pump efficiency (%). P_w = Pump water power (kW). P_M = Pump shaft power (kW)[18].

3. Research Methodology

The steps of the flowchart procedure as shown in Figure 2.

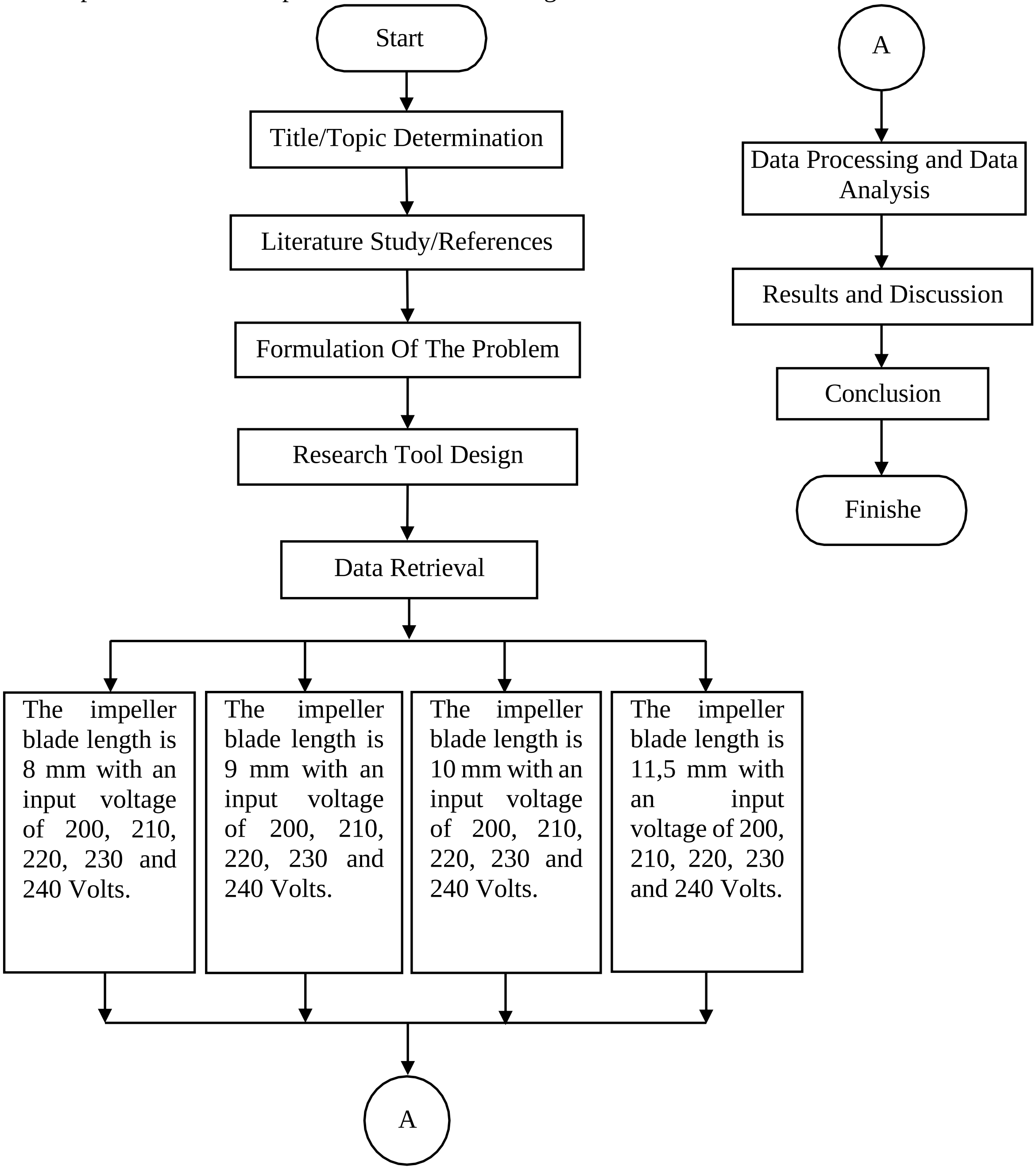

Figure 2. Research Methodology Flowchart

4. Discussion

In this peripheral pump research, a single pump arrangement was carried out by varying the input electrical voltage of 200 Volts, 210 Volts, 220 Volts, 230 Volts and 240 Volts and the length of the impeller blade with a length of 8 mm (standard), 9 mm, 10 mm, and 11.5 mm.

4.1 *Relationship between Input Voltage V_{in} (Volt) and Peripheral Pump Head H_p (m)*

In this study, the pump head is one of the values sought, to find out the pump head value, a pressure gauge and vacuum gauge are used. The graph of the relationship between the input electrical voltage V_{in} (Volt) and the peripheral pump head H_p (m) can be seen in Figure 3.

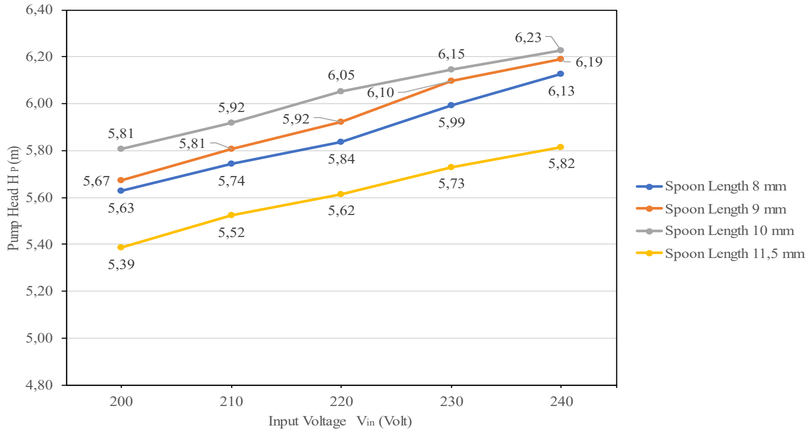

Figure 3. Relationship between Input Voltage V_{in} (Volt) and Peripheral Pump Head H_p (m)

In Figure 3. above, it is explained that the greater the input voltage used. The greater the head produced. This is caused by the input voltage entering the drive motor, which causes the impeller to rotate faster. As a result, the power given to each blade to the fluid increases rapidly, so the head also increases.

In this study, it was found that the data produced on the pump head value of each impeller variation with a blade length of 8 mm, 9 mm, 10 mm and 11.5 mm continued to increase along with the increase in the input voltage used. It can also be seen that the head value for the blade length variations of 9 mm and 10 mm increased compared to the blade length of 8 mm (standard). Then there was a decrease in the pump head at the 11.5 mm variation. The increase in head on the addition of the blade length that occurred was caused by the energy added to the fluid by a number of impeller blades (impeller blades) becoming greater (the energy when the water circulates becomes greater). Meanwhile, the decrease in the head value at the blade length variation of 11.5 mm occurred because the energy added to the fluid by a number of impeller blades (impeller blades) did not circulate only in the impeller blade section, but also to the middle of the impeller (slippage occurred). The highest head value at the impeller blade length variation made was at the blade length of 10 mm.

4.2 Relationship between Input Voltage V_{in} (Volt) and Peripheral Pump Water Flow Q_{air} (lpm)

In this study, water discharge is one of the values sought, to find out the water discharge value, a rotameter measuring instrument is used. The graph of the relationship between the input electrical voltage V_{in} (Volt) and the peripheral water discharge of the pump Q_{air} (lpm) can be seen in Figure 4.

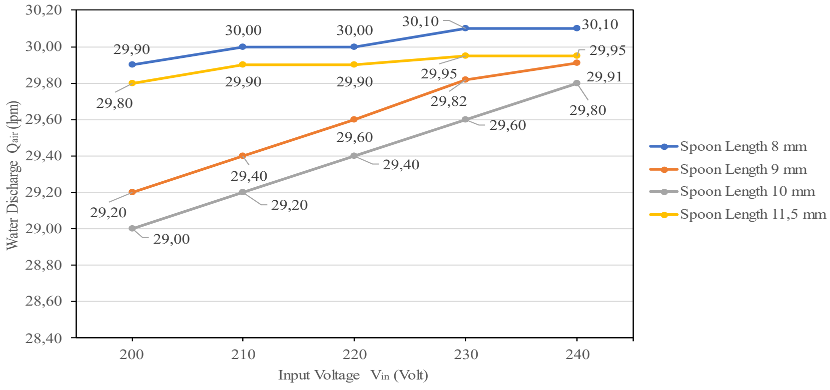

Figure 4. Relationship between Input Voltage V_{in} (Volt) and Peripheral Pump Water Flow Q_{air} (lpm)

In Figure 4. above, it is explained that the greater the input voltage used. The resulting discharge will also be greater. This is caused by the input voltage entering the drive motor, which causes the impeller to rotate faster. As a result, the suction pressure on the impeller will be greater, so that the discharge will increase.

In this study, it was found that the standard blade length of 8 mm and the variation of blade lengths made of 9 mm, 10 mm, and 11.5 mm produced a certain limit of discharge value even though the input voltage has been increased. This indicates that the discharge value produced has reached the maximum point that can be produced by the impeller on the peripheral pump. The impeller with a standard blade length (8 mm) gets the largest discharge value compared to the blade length that is varied with the highest value at an input voltage of 240 Volts of 30.10 lpm. Then followed by a blade length of 11.5 mm with the highest discharge at an input voltage of 240 Volts of 29.95 lpm, and a blade length of 9 mm with the highest discharge at an input voltage of 240 Volts of 29.91 lpm, and a blade length of 10 mm which has the smallest discharge, namely having the highest discharge value at an input voltage of 240 Volts of 29.80 lpm.

4.3 Relationship between Input Electrical Voltage V_{in} (Volt) and Peripheral Pump Efficiency η_{pump} (%)
The comparative efficiency between the water power owned by a flow and compared to the motor power as the main drive of the shaft using electric current. The graph of the relationship between the input electric voltage Vin (Volt) and the efficiency of the peripheral pump ηpump (%) can be seen in Figure 5.

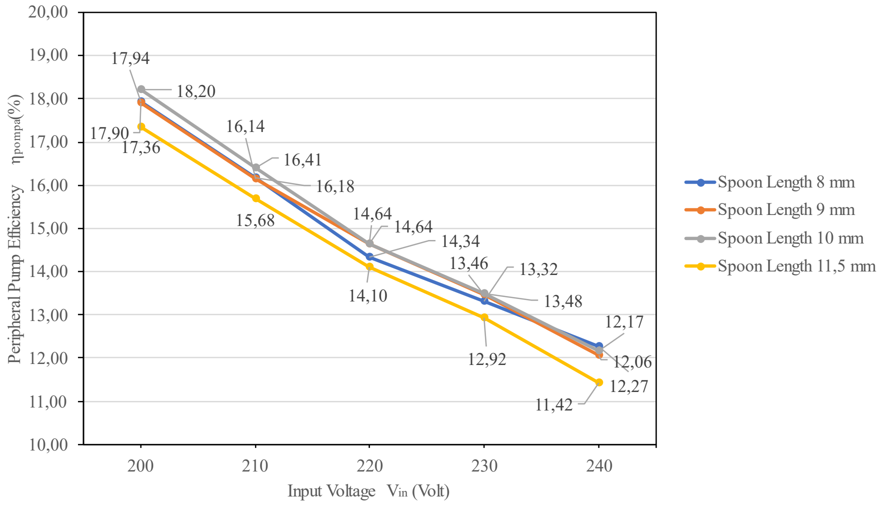

Figure 5. Relationship between Input Electrical Voltage V_{in} (Volt) and Peripheral Pump Efficiency η_{pump} (%)

From Figure 5. above, it is a graph of the relationship between input electrical voltage and peripheral pump efficiency based on variations in the length of the standard impeller blades of 8 mm, 9 mm, 10 mm, and 11.5 mm. Where efficiency is influenced by several factors, one of which is pressure, discharge, voltage and current released during testing.

In this study, it was found that the smaller the input voltage used, the greater the efficiency of the peripheral pump produced. If the input voltage used is greater, the resulting efficiency will be smaller. This happens because the water power produced does not match the motor power provided. In addition, the comparison of the efficiency of the peripheral pump has several differences, namely where the lowest efficiency is at a blade length of 11.5 mm and the highest efficiency occurs at a blade length of

10 mm. While for the blade length of 9 mm and 8 mm (standard) it produces a constant increase in efficiency.

5. Conclusion

From the results of testing and discussion, it can be concluded that:

1. The length of the impeller blades used in this study varied, namely 8 mm (standard), 9 mm, 10 mm, and 11.5 mm. The head and efficiency values produced in each variation showed differences. The highest head value was recorded at an impeller blade length of 8 mm (standard), which was 6.13 m. At variations in impeller blade lengths of 9 mm and 10 mm, there was an increase in head of 0.98% and 1.63% respectively compared to the head at the standard impeller blade length (8 mm). Conversely, at an impeller blade length of 11.5 mm, there was a decrease in the head value of 5.06%. In addition, the efficiency value also showed variations. At an impeller blade length of 10 mm, efficiency increased, while at an impeller blade length of 9 mm there was a decrease, with the highest decrease in efficiency occurring at an impeller blade length variation of 11.5 mm compared to the efficiency of the standard impeller blade (8 mm).
2. The higher the input voltage used in this study, which is 240 Volts, the greater the head produced. However, increasing this input voltage causes efficiency to decrease. This is due to the difference between the water power produced and the motor power provided. Increasing the input voltage can indeed increase the head, but on the other hand, the resulting efficiency is actually reduced.

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