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Impeller design for centrifugal pump with number of 5 blades driven four stroke 40 cc petrol engine

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Abstract

An impeller with five blades was designed to enhance water discharge from the volute. The increased number of blades was expected to exert a more potent force on the water due to a larger surface area. However, excessive blade numbers could obstruct inlet water flow, reducing discharge efficiency. Therefore, a restriction was applied to optimize the blade count. The impeller was developed using an experimental approach, as most designs typically feature four to seven blades. Performance tests were conducted by varying the outlet pipe width through different valve openings, and the effects on water discharge and velocity were analyzed. The results indicated that increasing the rotational speed (rpm) led to a higher discharge rate. At 5,702 rpm with a 100% valve opening, the maximum discharge of 1.426 L/s was achieved, while at 3,536 rpm with a 25% valve opening, the lowest discharge of 0.18 L/s was recorded. The velocity analysis showed that the highest speed of 14.17 m/s occurred at 5,702 rpm with a 25% valve opening, whereas the lowest speed of 2.74 m/s was observed at 3,536 rpm with a fully open valve. These findings confirm that increased valve openings enhance discharge and reduce water velocity due to outlet pipe diameter variations.

Keywords: Centrifugal, Pump, Impeller, Blade

Abstrak

Sebuah impeller dengan lima sudu telah dirancang untuk meningkatkan debit air yang keluar dari volute. Peningkatan jumlah sudu diharapkan dapat memberikan gaya yang lebih besar pada air akibat luas permukaan yang lebih besar. Namun, jumlah sudu yang berlebihan dapat menghambat aliran air masuk ke inlet, sehingga mengurangi efisiensi debit. Oleh karena itu, pembatasan jumlah sudu diterapkan untuk mengoptimalkan desain impeller. Impeller ini dikembangkan menggunakan pendekatan eksperimental, karena sebagian besar desain umumnya memiliki empat hingga tujuh sudu. Pengujian kinerja dilakukan dengan memvariasikan lebar pipa outlet melalui bukaan katup yang berbeda, dan dampaknya terhadap debit serta kecepatan air dianalisis. Hasil pengujian menunjukkan bahwa peningkatan kecepatan putaran (rpm) menghasilkan debit air yang lebih tinggi. Debit maksimum sebesar 1,426 L/s dicapai pada 5.702 rpm dengan bukaan katup 100%, sedangkan debit terendah sebesar 0,18 L/s tercatat pada 3.536 rpm dengan bukaan katup 25%. Analisis kecepatan menunjukkan bahwa kecepatan tertinggi sebesar 14,17 m/s terjadi pada 5.702 rpm dengan bukaan katup 25%, sementara kecepatan terendah sebesar 2,74 m/s diamati pada 3.536 rpm dengan katup terbuka penuh. Hasil ini mengonfirmasi bahwa meskipun peningkatan bukaan katup meningkatkan debit air, kecepatan aliran berkurang akibat variasi diameter pipa outlet.

Keywords: Pompa Sentrifugal, Impeler, Sudu

INTRODUCTION

The impeller is a centrifugal pump's heart, significantly affecting its hydraulic performance. Research by Zhang et al. [1] showed that Gaussian process regression models could optimize impeller design, improving efficiency and reducing hydraulic losses for specific centrifugal pump models. Similarly, research involving blade curvature variations illustrates how such changes can affect performance metrics such as head, efficiency, and cavitation behaviour within the pump [2] [3].

In addition, a thorough understanding of the flow dynamics inside the impeller can also result in significant performance improvements. For example, Jiang et al. reviewed design considerations that enable centrifugal pumps to handle gas-liquid two-phase flows, identifying the critical impact of flow patterns on pump performance [4]. Computational approaches continue to play an integral role in this field, as noted by Rehman et al.[5], who highlighted the effectiveness of simulation in studying the implications of design changes on hydraulic performance.

The volute design is also critical to ensure effective conversion of kinetic energy from the impeller into pressure energy, and several studies have focused on optimising the volute configuration. Bakytuly used the Taguchi method to assess the effects of the volute tongue angle, impeller diameter, and blade angle on overall performance metrics [6]. The findings align with previous research emphasising the relationship between volute geometry and hydraulic efficiency, confirming that modifications to the volute structure can significantly improve operational efficiency [7].

In addition, as important as considering the individual components separately, it is equally important to evaluate their interaction within the pump system. For example, the effect of tandem blades on flow characteristics has been investigated, showing how their configuration can result in better hydraulic performance [8]. Likewise, recent research by Han et al. examined how coupling motor flow analysis with pump operation can aid in diagnosing performance issues, thereby improving reliability and maintenance strategies[9][10].

This study aims to determine the pump discharge from the impeller we design so that the flow rate is known from the rpm variation and the output pipe. This research is very important in determining what pumps are suitable for use based on the resulting discharge. This research is helpful for pump designers so that they can design pumps according to usage based on the variable discharge of water produced so that they can contribute to society, for example, in agriculture to irrigate rice and also in shallot plantations for watering shallots; this requires us to know the discharge in the pump.

MATERIAL AND METHODS

Materials and tools

Materials: Scrap aluminium was used to cast the impeller, and wood was used to burn the casting furnace. The first tool used was the 3D model application, which was used to design the impeller by drawing its 3-dimensional model. Kup and drag are used to cast the impeller pattern.

Methods

The research was used to design an impeller with a 3D model and then make a 3D model by castings with aluminium. After being finished, the impeller is installed in the pump which is then tested for performance, namely calculating the water discharge with an output pipe of 0.75 inches with the opening of the valve divided into 4, namely the first with 25% open, second 50% open, third 75% open and fourth 100% open. Volume and time measurements are taken to calculate the discharge from the first to the fourth position.

A 3D model of the impeller is created using a three-dimensional modeling application, and a pattern is produced through 3D printing with ABS material. Then, an aluminum casting mold is fabricated using the 3D-printed pattern, which is then placed inside the casting mold. Next, the aluminum is melted in a furnace and prepared as the casting material. Finally, the impeller pattern is removed, and the molten aluminum is poured into the casting mold.

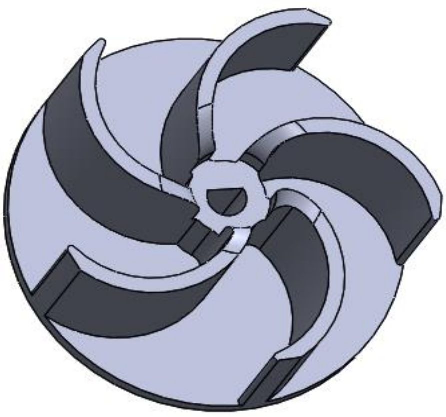

Figure 1. 3-Dimensional modelling of the impeller

The process of creating the impeller model was as follows: First, the sketch plane, such as the front plane, was selected to draw the basic outline of the impeller. A sketch tool, such as ‘Circle,’ was used to define the fundamental shape of the impeller. The diameter and center position were determined using the dimension tool. Next, the impeller geometry was constructed according to the design specifications. The blade profile was sketched accordingly since impellers generally have blades extending outward from the center. More complex curves were drawn using the ‘Spline’ tool when necessary. Once the sketch was completed, the ‘Extrude Boss/Base’ feature was applied to give the impeller section the required thickness. The appropriate depth was selected based on design specifications. If the impeller was symmetrical, the ‘Revolve Boss/Base’ tool was used to form the impeller shape according to the blade profile. Additional features were then incorporated to enhance the design. The ‘Fillet’ tool was used to round the blade edges and minimize wear. Holes and other necessary features were added using the ‘Extruded Cut’ tool based on the impeller’s design requirements. The impeller was designed using a 3D modeling application, SolidWorks, and fabricated as a pattern through 3D printing. This pattern was subsequently used to create castings from recycled aluminum. Aluminum was chosen as the material due to its relatively low melting point of 660.2 °C, as shown in Table 1. Compared to iron, aluminum was more straightforward to process and exhibited corrosion resistance, making it suitable for impeller manufacturing without requiring unique treatments.

Mould design and manufacture: Firstly, the design of the impeller is made considering the size, shape, and material to be used. Once the design is complete, a mould is made from sand, metal, or composite materials that can withstand high temperatures. Material Preparation: The casting material, usually a metal such as aluminum, iron, or stainless steel, is heated until it melts. The melting temperature depends on the type of material used. Liquid Metal Pouring: Once the material has liquefied, the liquid metal is poured into the prepared mould. It is important to pour carefully to avoid air bubbles or defects in the resulting impeller. Cooling and Testing: After the metal is poured, the mould is allowed to cool to allow the metal to solidify and take the shape of the impeller. Once the cooling process is complete, the mould is opened to remove the impeller. Post-Casting Processing: The resulting impellers often require quality inspection and finishing processes, such as grinding, honing, or painting, to improve strength and durability. Function Testing: Before the impeller is used in its actual application, tests are usually conducted to ensure it performs according to the expected specifications.

The submersible pump was powered by a four-stroke petrol engine with a capacity of 40 cc. This engine was widely available on the market, making it easily accessible. The pump was connected to the engine via a flexible shaft, which had a length of approximately 2 meters. As a result, the submersible pump was operated by transmitting power from the engine via the flexible shaft. Due to the 2-meter shaft length, the maximum water depth that could be pumped was limited to approximately 1.5 meters. Therefore, this pump was suitable for applications where the water surface was less than 2 meters deep. The petrol engine used in this system is shown in Figure 3.

Table 1. Physical properties of Aluminium [11]

Properties	**Purity Al %**	
	99,96%	**> 99%**
Density 20 ^{O}C		
Melting point ^{o}C	660,2	653 - 657
Specific heat (cal/g ^{O}C) (100 ^{O}C)	0,2226	0,2297
electrical conductivity %	64,94	59 anil
Electrical resistance coefficient Temperature (^{O}C)	0,00429	0,0115
Coefficient of expansion (20 -100 ^{O}C)	23,86 x 10^{-6}	23,5 x 10^{-6}
Crystal Type, Lattice Constant	Fcc, a 4,013 kX	Fcc, a 4,04 kX

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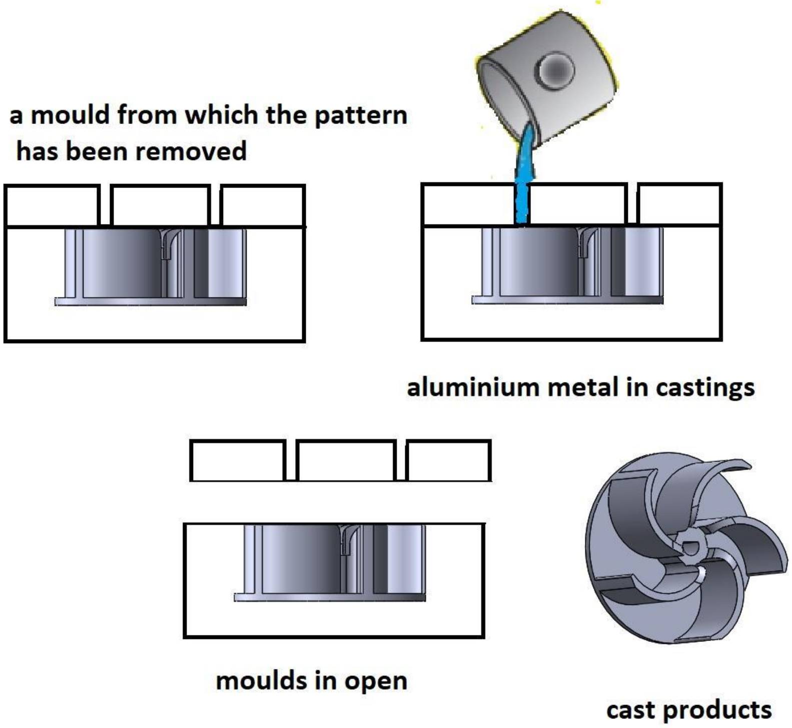

Figure 2: Impeller casting process

Figure 3. Pump drive of a 40 cc four stroke petrol engine

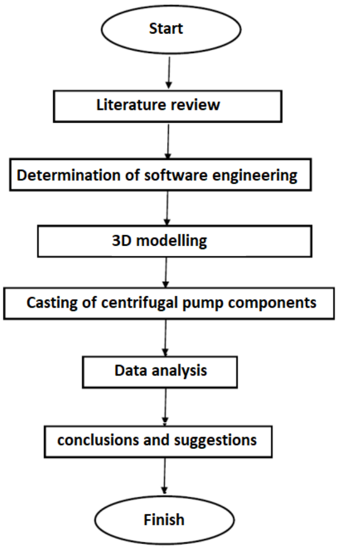

Figure 4. Experimental flow diagram for impeller design and testing

RESULTS AND DISCUSSION

The impeller was designed with five blades to increase the volume of water discharged from the volute. Additionally, with five blades, the force exerted on the water was expected to be stronger as the blades pushed the water with a greater surface area. The number of blades was also limited because an excessive number could obstruct the water entering the inlet, reducing the water flow and resulting in a lower discharge rate. Therefore, a restriction was applied to the number of blades in the impeller design.

This design was developed using an experimental method, as most impellers in various designs typically contain between four and seven blades. Consequently, an impeller with five blades

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was selected for testing, and the water discharge was evaluated by varying the outlet pipe width through different valve opening adjustments. The results of the tests are presented in Figures 5 to 8.

Figure 5 shows that the greater the driving rpm, the greater the discharge, where 3,536 rpm at 25% open valve produces a discharge of 0.18 litres/s while 5,702 rpm produces a discharge of 0.252 litres/s. The 50% open valve, at 3,536 rpm, produces a discharge of 0.370 litres/s, and at 5,702 rpm, a discharge of 0.735 litres/s. For the 75% open valve at 3,536 rpm, a discharge of 0.668 litres/s and at 5,702 rpm a discharge of 0.668 litres/s and 5,702 rpm a discharge of 1,283 litres/s and finally for the 100% open valve at 3536 rpm a discharge of 0.780 litres/s and 5,702 rpm a discharge of 1,426 litres/s is produced. So, the most significant discharge was at 5,701 rpm, with the valve open at 100%.

From Figure 6, it can be seen that the greater the driving rpm, the greater the speed where 3,536 rpm at 25% open valve produces a speed of 10.11 m/s while 5,702 rpm produces a speed of 14.17 m/s. For the 50% open valve, at 3,536 rpm, it produces a speed of 5.2 m/s; at 5,702 rpm, a speed of 10.33 m/s is produced. For the 75% open valve at 3,536 rpm, a speed of 4.17 m/s is produced, and at 5,702 rpm, a speed of 8.1 m/s is produced, and at 100% open valve at 3,536 rpm, a speed of 2.74 m/s is produced, and at 5,702 rpm, a speed of 5.01 m/s is produced. So, for the largest speed at 5,701 rpm, the valve should be open at 25%.

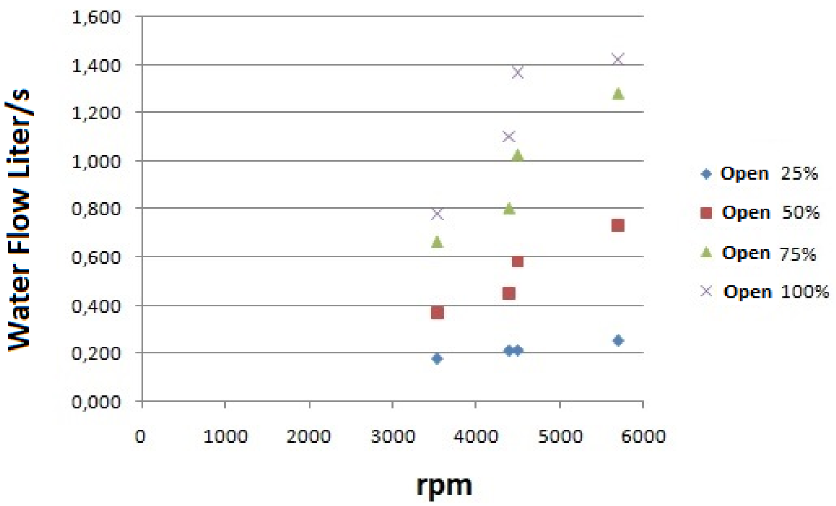

Figure 5. Measurement of rpm against water discharge for valve opening

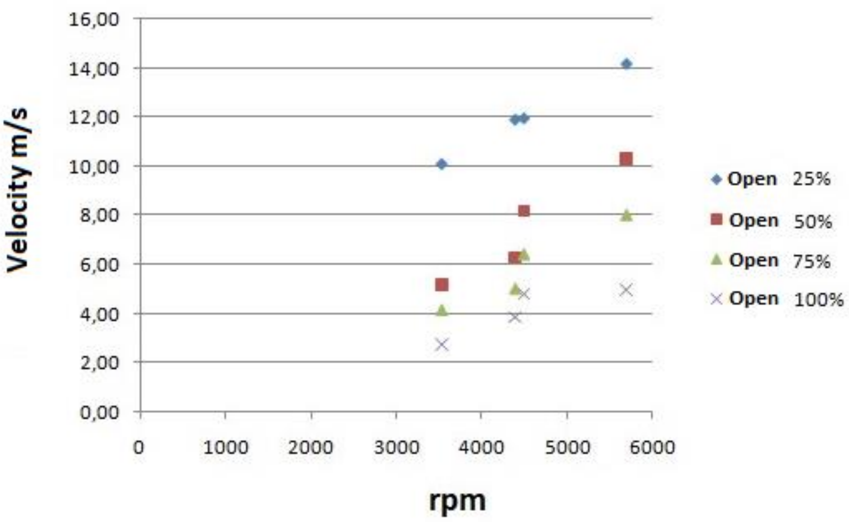

Figure 6. Measurement of rpm against water velocity for valve opening

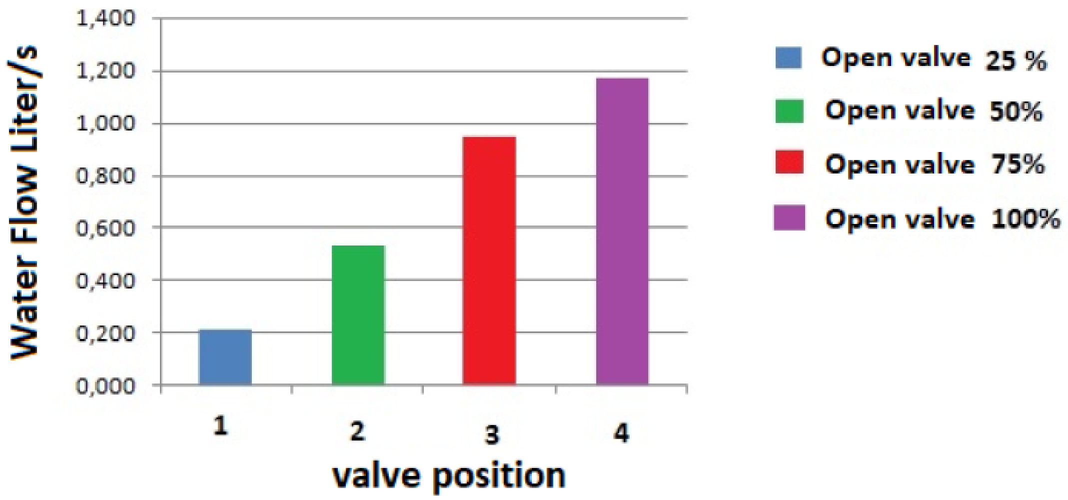

Figure 7. Valve opening against water discharge

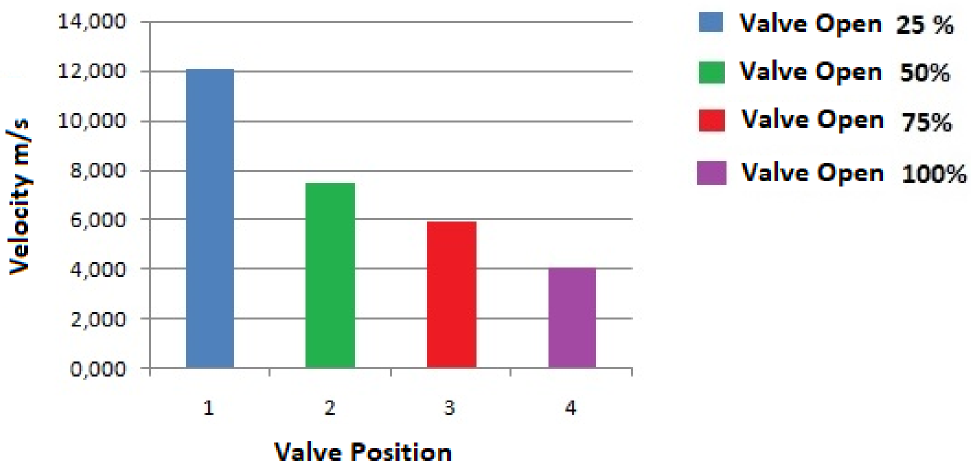

Figure 8 Valve opening against speed

Figure 7 shows that the average discharge at the 25% open valve is 0.214 litres/s; at the 50% open valve, it is 0.535 litres/s; at the 75% open valve, it is 0.947 litres/s; and at the 100% open valve, it is 1.170 litres/s. Thus, the water discharge increases with the valve's opening.

Figure 8 shows that the average speed at the 25% open valve is 12.04 m/s, at the 50% open valve, it is 7.057 m/s, at the 75% open valve, it is 5.909 m/s, and at the 100% open valve, it is 4.108 m/s. The water speed decreases with the valve opening because the diameter of the outlet pipe decreases.

CONCLUSION

Based on the analysis, the performance of a centrifugal pump with a five-blade impeller, as designed in this study, was evaluated. The results indicated that the average discharge for a 0.75-inch outlet pipe was 1.170 L/s, with an average engine speed of 4,534 rpm. These findings confirm that increasing the rotational speed (rpm) and valve opening significantly affects the water discharge and velocity. The maximum discharge of 1.426 L/s was achieved at 5,702 rpm with a 100% valve opening, while the minimum discharge of 0.18 L/s occurred at 3,536 rpm with a 25% valve opening. Furthermore, the highest water velocity of 14.17 m/s was recorded at 5,702 rpm with a 25% valve opening, whereas the lowest velocity of 2.74 m/s was observed at 3,536 rpm with a fully open valve. These results indicate that although increasing the valve opening enhances water discharge, it reduces water velocity due to changes in the outlet pipe diameter. Using a submersible system with a flexible 4-stroke motor drive, the centrifugal pump design is considered suitable for water pumping applications in shallow water areas. Further research is recommended to measure the pump head by implementing an irrigation system to achieve optimal performance.

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