ANALYSIS OF THE NUMBER AND ANGLE OF THE IMPELLER BLADE TO THE PERFORMANCE OF CENTRIFUGAL PUMP

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Abstract

The paper discusses the performance of the pump in relation to the impeller. The impeller section is determined by the number and angle of the blades. Therefore, the purpose of this study was to analyze the role of the number and angle of impeller blades on the performance (discharge and discharge pressure) of centrifugal pumps based on experiments and simulations.

The method used is experiment and simulation. Using a centrifugal pump type GWP 20/4 SW, Maximum Output: 6.5 HP/3500 rpm, Inlet/Outlet: 2 Inch, Dimensions: 475×375×370 mm. Experiments and simulations by varying the number of blades 2, 4, and 6 with a blade tilt angle of 130°, 150°, and 160°. For flow simulation using solid works program.

The results show that pump performance is related to discharge pressure, impeller with 2-blades and an angle of 130° the pressure increases 0.45–2.45 bar, for 150° increases 0.14–2.96 bar, and 160° increases 0.29–3.07 bars. For a 4-blade impeller and an angle of 130°, the pressure increases by 0.48–3.12 bar, for 150° it increases by 0.39–3.39 bar, and for 160° it increases by 0.36–3.48 bar. While the impeller for 6-blades with an angle of 130° the pressure increases from 0.6 bar to 3.72 bar, for 150° increases from 1.36 to 4.34 bar, and 160° increases by 0.36–4.74 bar. While it related pump performance to flow rate, increasing the number of blades causes a decrease in flow rate. The highest flow rate is in a 2-blade impeller with a blade angle of 130° is 404.91 l/s. The lowest flow rate is on a 6-blade impeller with an angle of 160° is 279.66 l/s.

Keywords: pump performance, centrifugal pump, impeller, number of blades, blade angle, simulation, experiment.

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1. Introduction

Water is a very vital need for survival, be it humans, animals or plants. Besides irrigation needs, but also for the supply of raw water, clean water, industrial water, electricity, plantations and other business activities that require water. With the increase in population, the need for water also increases. So that pumps are necessary to drain water from one place to another, and pumps are needed in human life in various fields [1, 2]. The pump serves to move the fluid through the pipe from one place to another [3].

The function of the pump is to change the mechanical energy of the shaft that moves the blades into kinetic energy and pressure in the form of the head in the fluid. The impeller is an important component in a centrifugal pump, and the most important part is the number and angle of the blades. This affects the performance of the pump. Pump performance is determined by the output pressure, flow capacity or flow rate, and suction strength [4].

Pump design requires a trial-and-error process, reducing the pump manufacturer's profit margins. For analytical reasons, besides experiments, simulations were also carried out at the pump design and construction stages [5]. Instability and dynamic phenomena can be studied with the help of simulation. Simulation can provide fairly accurate information about fluid behaviour, thus helping in evaluating pump performance [6].

The need for pumps in human life in various fields. For agriculture, pumps are widely used in the irrigation system so that the agricultural system continues to run even in the dry season,

in providing drinking water for the community, pumps are used to distribute drinking water from PDAM to people's homes, pumps are a tool that facilitates daily human work [7]. Therefore, research is needed that discusses the effect of the impeller exit angle (β_2) on performance which includes discharge and exhaust pressure in centrifugal pumps. The role of the number of blades and the angle of the blade on the impeller affect the resulting pump pressure.

To optimize pump performance, a pump impeller is needed which plays an important role in determining the pump output pressure and flow capacity. The influence of the number of blades and the angle of the blades will cause the number of blades to change and affect the resulting pump pressure.

Research on the optimization of centrifugal pump impeller performance using design standards. Simulation is used to validate experimental test results. The experimental results were analyzed for the best combination of parameters and compared with the original pump. Research on the optimization of pressure and efficiency of centrifugal pumps to get high efficiency in using low power in operation. This study increases the head and efficiency of the centrifugal pump by changing the impeller blades and the exit angle of the centrifugal pump blades to get optimal head and efficiency [8].

This research on Centrifugal Pump Impeller Design Optimization research with the CFD approach discusses the stages of pump construction design. Based on the design results, to determine the optimal number of blade variations [9].

Research on the effect of the inlet impeller reverses 6 angles on the characteristics of the FM 50 centrifugal pump. This study discusses the effect of the inlet angle of the impeller (β_1) of the pump on the centrifugal pump head for each impeller with an intake angle. The results showed that the value (β_1) of the impeller did not affect the performance of the pump, but because the circulation in the impeller caused the performance of the pump to change. Based on the results of the study, it is known that the greater the head value (β_1), the hydraulic power of the pump will increase. The pump flow rate also increases. On the other hand, the greater (β_1), the smaller the pump efficiency produced [10].

Numerical simulation of backward impeller type centrifugal pump with variations in rotation and pump discharge. Numerical simulations were carried out on 2D and 3D steady flow with a standard turbulent k-epsilon model. Simulation by varying the speed and flow of the pump. Then the simulation results are validated with experimental results. The results obtained in the 2D numerical research are very different from the experimental results. In the 3D simulation, there is a backflow phenomenon [11].

Therefore, researchers conducted experiments and simulated the effect of the impeller exit angle on performance which includes discharge, discharge pressure on a centrifugal pump by using the influence of the number and exit angle of the impeller.

2. Materials and methods

2.1. Centrifugal pump specifications

The type of pump used in this study is GWP 20/4 SW. Following are the specifications for the Centrifugal Pump Type GWP 20/4 SW, Maximum Output: 6.5 HP/3500 RPM, Inlet/Outlet: 2 Inch, Dimension: 475×375×370 mm. The impeller design is shown in **Fig. 1**.

Fig. 1 shows the design of the blade position and blade angle for 2 variations of the blade angle of 160°. Manufacturing this impeller uses the welding method so that it can form a precise construction. The number of blades 2, 4, and 6 varied with blade angles of 130°, 150°, and 160°.

2.2. Experimental setup

The study used a 2-inch GWP 20/4 SW centrifugal pump. The research was conducted by varying the number and angle of the blades using experimental and simulation methods. In this study, the number of blades 2, 4, and 6 varied with blade angles of 130°, 150°, and 160°. **Fig. 2** shows the experimental setup.

The experimental set-up consists of 3 main parts, namely preparing the equipment to be tested, preparing the pump, and taking data.

Fig. 1. Design of impeller for 2-blade 160°: *a* – Front view; *b* – Section A-A

Fig. 2. The experimental setup

The research procedure includes:

1. Preparing the equipment according to the experimental setup.
2. Prepare the pump impeller with the number of blades and the angle to be tested.
3. Install the impeller on the volute housing and pump impeller housing.
4. Install the measuring instrument.
5. Data collection.

2. 3. Simulation

Flow simulation using the solidworks program. This program can analyze the integrated and can simulate the flow of liquids that are adapted to actual conditions.

2. 3. 1. Boundary Conditions

1. Initial Data Collection.

At this stage, data collection on information related to pumps is carried out with the number of blades 2, 4, and 6 and the angle of inclination of the blades 130°, 150°, and 160°.

2. Parameter Setup Process.

In the simulation, the process to get results on the number and angle of the blades, setup parameters ranging from messing, boundary conditions, and goals. Referring to the internal type analysis, fluid type water, turbulent flow model, condition inlet (static pressure), outlet (total pressure) and adiabatic pump wall.

3. Data Retrieval.

At the data collection stage, the simulation runs the process to get the results of the discharge and the total pressure generated on the number and angle of the blade angle.

3. Result and Discussion

3.1. Result

The results of the research are pump performance data including discharge, pump pressure as shown in **Fig. 3, 4**. The visual results of the pump flow simulation are as shown in **Fig. 5**.

Fig. 3. Flow rate to the number of blades with variations in angles of 130°, 150° and 160° in experiments and simulations

Fig. 4. Pump pressure on the number of blades with variations in angles of 130°, 150° and 160° in experiments and simulations

Fig. 3 shows that there are three areas related to flow rate and discharge pressure: Area 1 is the pressure drop due to eddy currents in the opposite direction of rotation. Area 2 is a change

in pressure because of the rotation of the blades, thus affecting the pump pressure. Area 3 is an occurrence of whirlpools caused by the flow of water hitting the impeller walls, causing the fluid flow to be restrained.

Fig. 5. Simulation results of variations in the number of blades and blade angles:
a – 2 blades, 130°; *b* – 2 blades 150°; *c* – 2 blades 160°; *d* – 4 blades 130°; *e* – 4 blades 150°;
f – 4 blades 160°; *g* – 6 blades 130°; *h* – 6 blades 150°; *i* – 6 blades 160°

3. 2. Discussion

Based on the results of experiments and simulations got the number of blades 2, 4, and 6 with a tilt angle of 130°, 150°, and 160°. In the volute outlet area, there is a pressure drop. This is because the whirlpool is in the opposite direction of the water flow.

In an impeller with several two blades and an angle of 130°, four vortex flows are in opposite directions of flow. This current is present at the volute outlet, volute wall and pump outlet line.

That results in a pressure drop. The distance between the eddies also affects the pressure drop. The closer the distance between the vortexes, the greater the pressure drop, causing differences in fluid flow velocity. While the increase in the number of blades 4 and 6, the pressure drop is getting smaller. An increase in the number of blades causes an increase in thrust pressure and an increase in fluid flow velocity.

In an impeller with two blades and an angle of 150° , there are three opposite vortices at the bottom of the volute housing line and the pump outlet line. However, the sum of the four blades caused a vortex. Its location, the housing volute outlet is next to the nearest vortex, while in the six-blade impeller, the vortex flow is at the bottom of the volute outlet. This is also almost the same as the angle of 130° . It's just that the location and pressure drop are different. As for the impeller with two blades and an angle of 160° , the pressure drops at the outlet side.

For the number of blades, four and six did not experience a decrease in pressure.

At the impeller inlet, there is a change in flow pressure. The change in colour level shows that. Where the more blades, the greater the pressure change. For two blades whose angles are 130° , 150° , and 160° , there is a different pressure rise. An angle of 130° the pressure increases 0.45–2.45 bar, for an angle of 150° it increases –0.14–2.96 bar and an angle of 160° increases by 0.29–3.07 bar. For four blades with angles of 130° , 150° and 160° , there is a different pressure rise. For an angle of 130° , the pressure increases 0.48–3.12 bar, for an angle of 150° it increases by 0.39–3.39 bar and an angle of 160° increases by 0.36–3.48 bar.

Even though the six-blade angles are 130° , 150° , and 160° , there are differences where at the 130° angle the pressure increases from 0.6 bar to 3.72 bar, for the 150° angle it increases from 1.36–4.34 bar, and at an angle of 160° , increase by 0.36–4.74 bar.

In the area between the tip of the blade and the flow guide plate, there is a whirlpool caused by the flow of water hitting the impeller wall, causing a fluid flow to be obstructed. The large blade rotation produces a large resistance force so that the inflow is low. An increase in the number of blades will result in a decrease in the flow rate. The highest flow rate is found in the number of two blades with a blade angle of 130° . For comparison, the lowest flow rate is found in the six blades with an angle of 160° . There is a difference where the greater the number of blades and the greater the angle of the blade, the higher the pressure. The highest pressure is obtained in the amount of six blades with an angle of 160° , while the lowest pressure is obtained in the amount of two blades with an angle of 130° .

The research has not shown how much influence the number and angle of the blades on the pump impeller on the presence of cavitation, only discusses related to pump performance. In this study, only the impeller with the backward impeller type was used. So it is necessary to research other types.

It is necessary to develop pump studies related to the elimination of vortex flow that occurs at the outlet volute. This is very important because vortex flow increases the pressure drop. The presence of pressure drop in the outlet volute area causes the pump to cavitate. Cavitation is highly undesirable in a pumping system. Because of cavitation, the area of the fluid foam eruption experiences repeated shock pressures. So that shock pressure easily eroded the material in the area. In addition, losing pressure drop causes the flow to be smooth and without obstacles. So that the flow rate and the thrust of the fluid are getting bigger. This makes the pump performance better.

4. Conclusions

1. Pump performance related to discharge pressure, for an impeller with 2-blades and an angle of 130° , the pressure increases 0.45–2.45 bar, for 150° increases 0.14–2.96 bar, and 160° increases 0.29–3.07 bars. For a 4-blade impeller and an angle of 130° , the pressure increases by 0.48–3.12 bar, for 150° it increases by 0.39–3.39 bar, and for 160° it increases by 0.36–3.48 bar. While the impeller for 6-blades with an angle of 130° the pressure increases from 0.6 bar to 3.72 bar, for 150° increases from 1.36 to 4.34 bar, and 160° increases by 0.36–4.74 bar.

2. While it related pump performance to flow rate, increasing the number of blades causes a decrease in flow rate. The highest flow rate is in a 2-blade impeller with a blade angle of 130° is 404.91 l/s. The lowest flow rate is on a 6-blade impeller with an angle of 160° is 279.66 l/s.

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