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FLOW ANALYSIS IN PUMP AS TURBINES (PATs) USING ANSYS FLUENT SOFTWARE

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ABSTRACT

Pump As Turbines (PATs) is a small-scale power plant that uses hydropower as its driving force. The working principle is given the flow of water from a certain height into the pump output to produce pressure at the tip of the impeller blade and will rotate the impeller blades. In this research will be the optimization of Pump As Turbines (PATs) by changing the angle of the impeller blade tip to get the optimum design of Pump As Turbines (PATs) using Ansys fluent software. In using angle tip impeller blade 60^0, 45^0, 35^0, 30^0, and 25^0, pressure tip impeller blade the lowest on angle tip impeller blade 60^0 using incoming pressure 7 psi (0.483 bar) with a pressure value tip impeller blade 0.123 bar and the biggest one is angle tip impeller blade 25^0 using incoming pressure 14 psi (0.965 bar) with a pressure value tip impeller blade 0.543 bar. Based on the results of the impeller blade tip pressure obtained the optimal design of Pump As Turbines (PATs) is angle tip impeller blade 25^0 because of the critical angle of Pump As Turbines (PATs) if you use an impeller design less than 25^0 then the impeller blades will run out so that it can affect the resulting rotation.

***Keywords**: Pump As Turbines (PATs); angle tip impeller blade; Ansys fluent software.*

1. INTRODUCTION

In general, a pump is a working machine that functions to convert mechanical energy (rotating shaft work) into fluid energy and pressure, in Pump As Turbines (PATs) the working principle of a pump is reversed into a powerful engine that converts fluid potential energy into kinetic energy. On installation, the use of pumps as turbines is more practical, inexpensive, easily available in the market, and easy to maintain [1,5].

Pump As Turbines (PATs) are a small-scale power plant that uses hydropower as its driving force such as water sources or waterways by utilizing headwater and the amount of water discharge. Pump As Turbines (PATs) are given a water discharge from a certain height into the pump output to rotate the pump impeller blades. Discharge of water entering the pump output will produce pressure at the tip of the impeller blade, so it will rotate the impeller blade then produce a rotation to drive the generator and produce electrical energy [3,6].

Derakhshan researched to improve the efficiency of centrifugal pumps when operated as turbines, they focused on modifying the blade shape of the pump impeller. The results obtained numerically indicate an increase in efficiency if it is modified, the optimization results show an increase in torque, head, and hydraulic efficiency [2-5].

Ansys fluent is software in a computer that is used to simulate flow velocity, water pressure, and impeller tip pressure, so that it can know a clear picture of the working conditions at Pump As Turbines (PATs) [7].

In this study, the formulation of the problem is as follows: What is the effect of the angle of the tip of the impeller Pump As Turbines (PATs) on the pressure produced. How to design optimal Pump As Turbines (PATs) by changing the angle of the tip of the impeller blade. What is the profile of flow velocity and water pressure in Pump As Turbines (PATs) using Ansys fluent software.

The purpose of this research is: Optimizing the design of Pump As Turbines (PATs) by changing the angle of the blade tip on the impeller. Conduct analysis to find the optimal design of Pump As Turbines (PATs) by simulating using Ansys fluent software. Conducting tests on Pump As Turbines (PATs) to determine the profile of flow velocity and water pressure on Pump As Turbines (PATs) using Ansys fluent software.

2. METHODS

2.1. Research Methodology

In this research method, it is explained two types of stages that will be used in this study, namely the research system flow chart and data analysis flow chart. The flowchart is as follows figure 1:

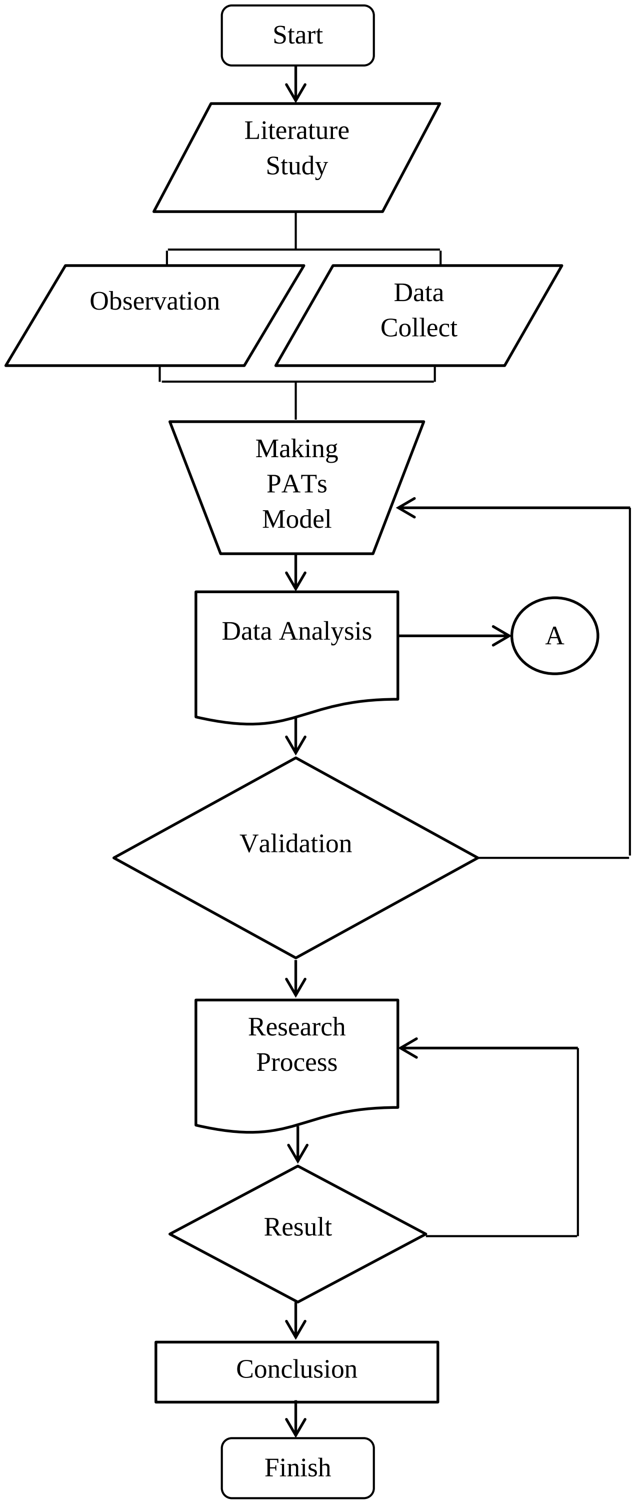

Figure 1. Research System Flowchart

2.2. Data Analysis

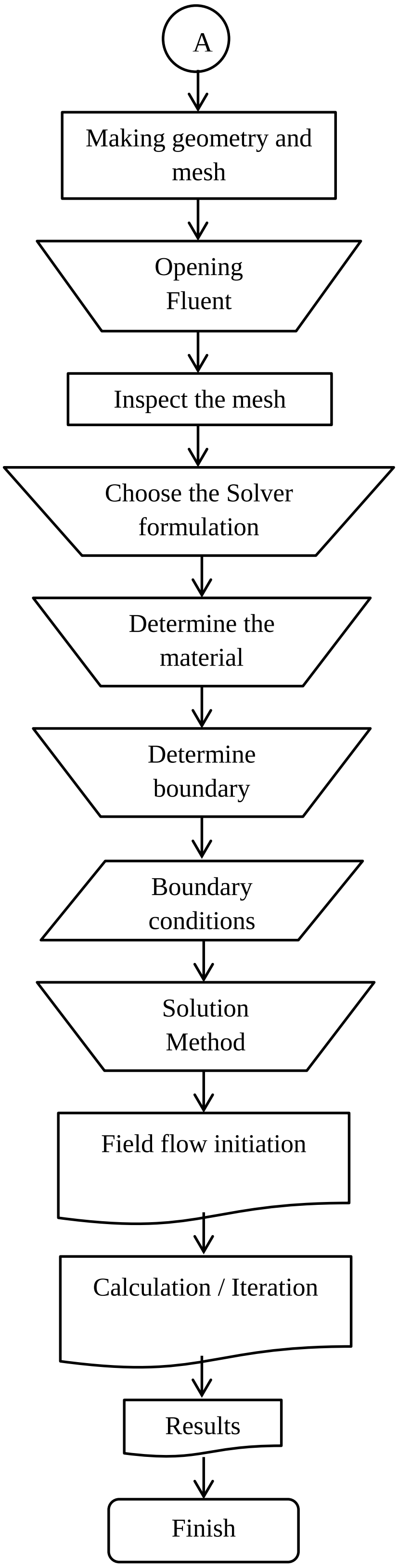

Figure 2. Data Analysis Flowchart

2.3. Research Process

The tip angle of the impeller Pump As Turbines (PATs) is the original 45 ° which has not changed the angle of the blade tip. The process of this research is to experiment with changing the design of the impeller blade tip angle and the inlet pressure to get the optimal Pump As Turbines (PATs) design. The research process that will be carried out is as follows:

a. Look for the influence of the impeller blade tip angle on pressure. The research process is to look for the effect of the impeller blade tip angle on the pressure generated by using the original Pump As Turbines (PATs) impeller blade tip angle 45°. In this study also experimented by changing the design of the Pump As Turbines impeller blade tip angle (PATs) to 30° and 60°, as well as different inlet pressures.

b. Finding the optimal design of Pump As Turbines (PATs) by changing the angle of the tip of the impeller blade
The research process to find the optimal design of Pump As Turbines (PATs) is by changing the angle of the tip of the impeller blade. In this study, the optimal tip angle of the impeller Pump As Turbines (PATs) from the results is looking for the effect of the impeller blade tip angle on the pressure generated.

The final research site is the workshop of the Mechanical Engineering Department, Faculty of Engineering, University of Majalengka.

2.4. The series of Pump As Turbines (PATs)

Pump As Turbines (PATs) specifications can be seen in table 1.

Table 1. Specifications *Pump As Turbines* (PATs)

Model	**SU-80**
Connection dia	80 mm
Delivery volume	40 m^3/h
Total head	36 m
Power speed	3600 rpm
Number of impeller blades	4 blade
Impeller blade tip angle	45°

The series of Pump As Turbines (PATs) systems shown in Figure 3.

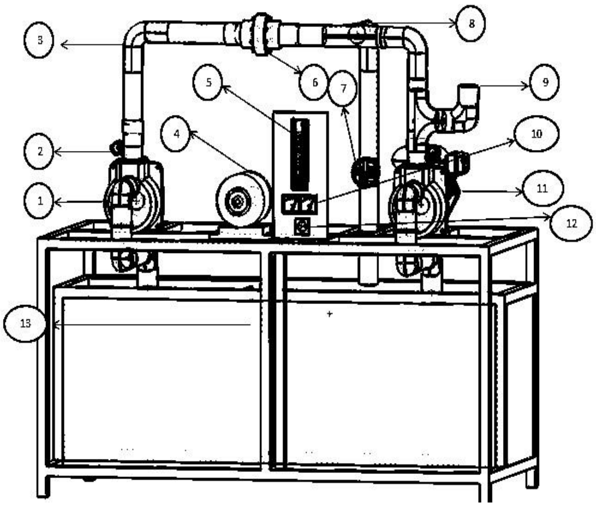

Figure 3. Pump As Turbines (PATs) Parts

Information:
1. *Pump As Turbines* (PATs).
2. *Pressure gauge.*
3. Pipe connection L.
4. Generator.
5. Manometer U.
6. *Orifice.*
7. Valve.
8. Pipe connection T.
9. Pipe cover.
10. Voltmeter & Wattmeter.
11. Centrifugal pumping machine (*input*).
12. Electric socket.
13. Weirmeter.
14. Frame.

2.5. Centrifugal pumping machine (*input*)

The specifications of the centrifugal pump machine (input) can be seen in table 2.

Table 2. The specifications of the centrifugal pump machine

Parameter	Specifications
Water exit and entrance diameter	80 mm
Displacement	48 m^3/h
Lift	25 m
Power speed	3600 rpm
Auto-suction high	5 m
Auto-suction time	2.5 min
Net weight	30 g

2.6. Equipment used

The equipment used in the analysis of Pump As Turbine (PATs) is as follows:
1. Toshiba laptops with Intel® Core ™ i5-3210M CPU @ 2.50Hz 2.50 GHz, 4GB RAM, and 64-bit operating system.
2. *Software SolidWorks.*
3. *Software Ansys Fluent V17.*
4. *Tachometer*
5. *Pressure gauge*

2.7. Ansys Fluent Procedure

The general steps for resolving Ansys fluent are as follows:

a. Make geometry and mesh on the model.
b. Choosing the right solver for the model (2D or 3D).
c. Import the mesh model (grid).
d. Check the mesh model.
e. Choosing a solver formulation.
f. Choose the basic equation that will be used in the analysis.
g. Determine the material properties to be used.
h. Determine the boundary conditions.
i. Set solution control parameters.
j. *Initialize the flow field.*
k. Perform calculations / iterations.
l. Check the results of the iteration.
m. Save the results of the iteration.
n. If needed, refine the grid then re-iterate to get better results.

3. RESULTS AND DISCUSSION

3.1. Data Collection

The data collection used in this study is experimental data with direct measurements of Pump As Turbines (PATs).

The measuring instrument used to measure fluid pressure is a pressure gauge with a maximum accuracy of 60 psi/4 bar, while for measuring the rotation speed of centrifugal pump machines (input) and Pump As Turbines (PATs) is a tachometer.

The results of data collection that have been carried out are as follows:

a. The first test (PATs)

In the first test (PATs) with the position of the gas lever slightly open, the results of measurements that have been made are as follows:

- The centrifugal pump (input) engine speed is 1871 rpm.
- Pump As Turbines (PATs) 1207 rpm.
- Incoming pressure of 7 psi.
- Exit pressure shows that it remains at zero or not available because it is the smallest scale of the measuring instrument, 2 psi, so it cannot read the results from 0-1 psi.

b. The second test (PATs)

In the second test (PATs) with a half-open gas lever position, the measurement results that have been made are as follows:

- The centrifugal pump (input) engine speed is 2262 rpm
- Pump As Turbines (PATs) 1510 rpm rotation.
- Inlet pressure of 10 psi.
- Exit pressure shows that it remains at zero or not available because it is the smallest scale of the measuring instrument, 2 psi, so it cannot read the results from 0-1 psi.

c. Third Testing (PATs)

In the third test (PATs) with the maximum gas lever position, the results of measurements that have been made are as follows:

- The centrifugal pump (input) engine speed is 2830 rpm.
- Pump As Turbines (PATs) Round of 1928 rpm.
- Inlet pressure of 14 psi.
- Exit pressure shows that it remains at zero or not available because it is the smallest scale of the measuring instrument, 2 psi, so it cannot read the results from 0-1 psi.

Based on data collection by making direct measurements of Pump As Turbines (PATs), which are obtained such as inlet pressure, outlet pressure, engine speed centrifugal pump (input), and Pump As Turbines (PATs). The results of pressure from a pressure gauge are then converted into units of the bar, while the results of data collection that have been done can be seen in table 3.

.

Table 3. Data collected from the data

Testing (PATs)	n_1 (rpm)	n_2 (rpm)	P_{in} (psi)	P_{in} (bar)	P_{out} (psi)
#1	1871	1207	7	0,483	NA
#2	2262	1510	10	0,689	NA
#3	2830	1928	14	0,965	NA

Information:
NA = not available
n_1 = Centrifugal pump engine speed
n_2 = Speed PATs
P_{in} = pressure inlet
P_{out}= pressure outlet

3.2. Making Pump As Turbines Model (PATs)

In making the centrifugal pump model used as Pump As Turbines (PATs) using SolidWorks software, the results of making this model are shown in Figure 4.

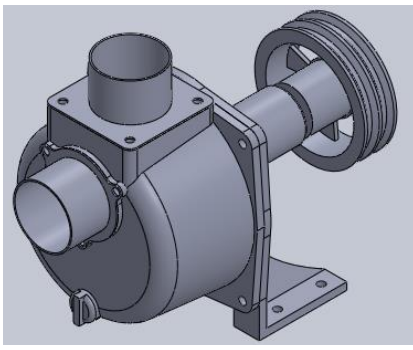

Figure 4. Centrifugal Pump

The result of making a centrifugal pump model, then the SolidWorks software file is converted to Ansys software, namely the IGES type (*.igs).

3.3. Stages of Data Analysis

a. Data analysis

The process of data analysis is to obtain simulation results using Ansys fluent software, then validated by collecting data directly from the measurement of Pump As Turbines (PATs).

The impeller blade tip angle on the centrifugal pump used in Pump As Turbines (PATs) is the original 45 ° which has not changed the blade tip angle. In table 3.2 are the analytical data that have been obtained in data collection, then entered in the process of boundary conditions when using Ansys fluent software.

Table 4. Experimental Data

Experiment	n_2 PATs	P_{in} (psi)	P_{in} (bar)	P_{out} (psi)
#1	1207	7	0,483	0
#2	1510	10	0,689	0
#3	1928	14	0,965	0

The data analysis process carried out is as follows:

a) Making Geometry and Mesh

Figure 5 shows the results of the geometric modeling of centrifugal pumps, and Figure 6 shows the results of making mesh.

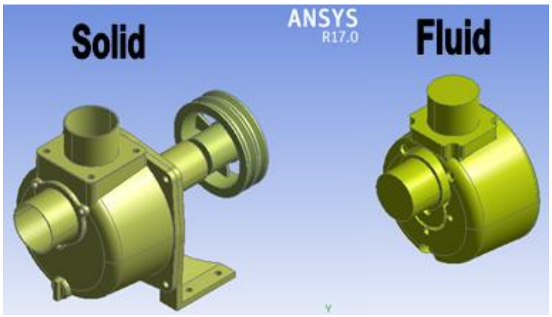

Figure 5. Geometry models of solid and fluid centrifugal pumps

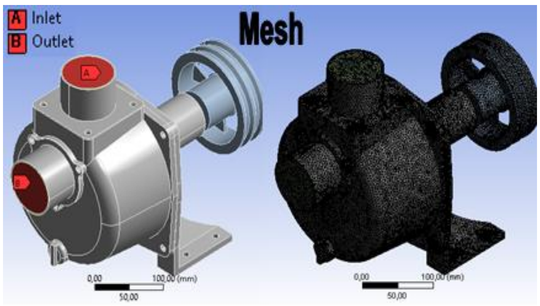

Figure 6. The meshing of centrifugal pumps

b) Opening Ansys Fluent

Figure 7 shows the initial process of Ansys fluent software

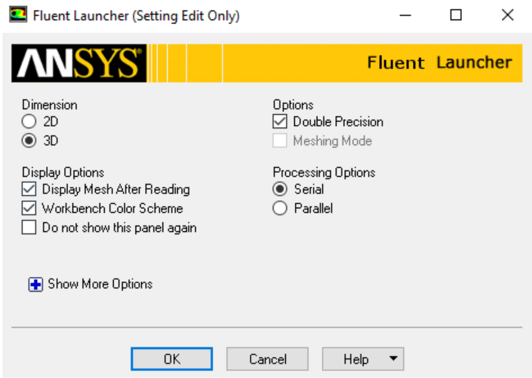

Figure 7. The initial process of Ansys Fluent

c) Check the mesh

The mesh model that has been opened in fluent must be checked first whether there is an error in the mesh or not, this mesh checking must be done to find out the error. After checking the data mesh model will appear on the fluent console if there is an error message on the fluent console the mesh model must be repaired before proceeding to the next step.

d) Choose the solver formation

Formation of solver in Ansys fluent, some several basic models and equations can be used. In this study, the viscous k-epsilon model and the k-epsilon model are realizable, because the viscous k-epsilon model is a fairly complete turbulence model with two equations that allow turbulent speed and stability of the computational side and adequate accuracy for various types of turbulent flow. In Figure 8 is the result of selecting the solver formulation.

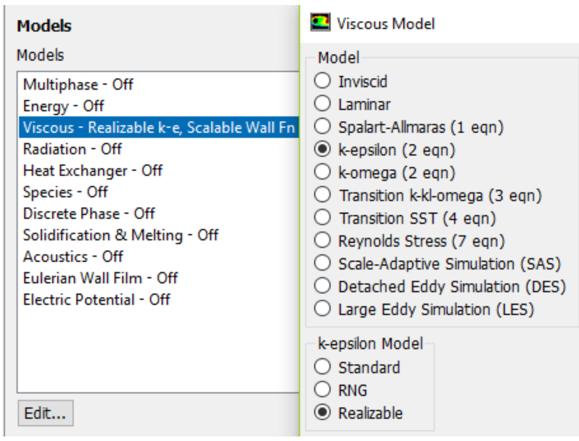

Figure 8. Results of solver formulation selection

e) Determine Material Properties

In modeling in gambit there is a geometry that must be defined conditions of material properties, the Pump As Turbines (PATs) model used there are two models, namely solid and fluid. In this study, the solid material is aluminum while the fluid is water, so in the process of this material, the aluminum solid material must be provided and the fluid water.

f) Determine The Boundary Conditions

Determine the boundary conditions of a model that has been made on a solid material gambit is defined as aluminum while the fluid is water. Material data used is available from the process of determining material properties.

g) Boundary Conditions

The boundary condition is to enter the parameters of the boundary conditions in the model that has been made, such as inward pressure, outgoing pressure, and Pump As Turbines (PATs) rotation as shown in Figure 9.

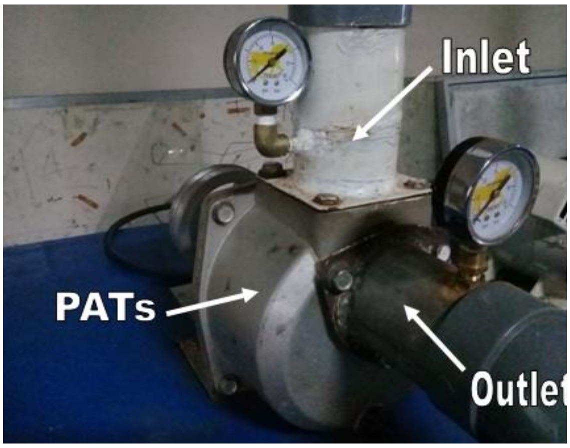

Figure 9. Pump As Turbines (PATs)

In the inflow type, the boundary conditions are pressure inlet and outflow type boundary conditions namely pressure outlet. In the process of boundary conditions in this data analysis, centrifugal pump inflows are 7 psi, 10 psi, and 14 psi, while the outflow at the centrifugal pump is considered 0 psi.

h) Solution Method

In this study using the coupled method because it can solve all the equations of continuity, momentum, energy, radiation, and turbulence simultaneously, resulting in a solution that is faster than the others.

i) Initialize The Flow Field

The data that has been input at the boundary condition is checked first in the process of initializing the flow field before doing the calculation.

j) Calculation / Iteration

In this calculation/iteration input any value, if you have a convergent result then the fluent will stop doing iteration.

b. Results of Data Analysis

In the process of analyzing this data is to see the pressure, speed, velocity vector, and impeller blade pressure. Data analysis using Ansys fluent software, with the impeller tip angle Pump As Turbines (PATs) is the original 45 ° which has not changed the tip angle. The results of data analysis are as follows:

a) Inlet pressure 7 psi (0.483 bar)

- Pressure

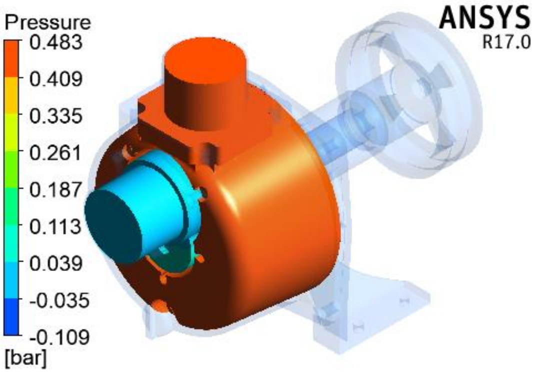

Figure 10. Pressure results on Pump As Turbines (PATs)

- Velocity

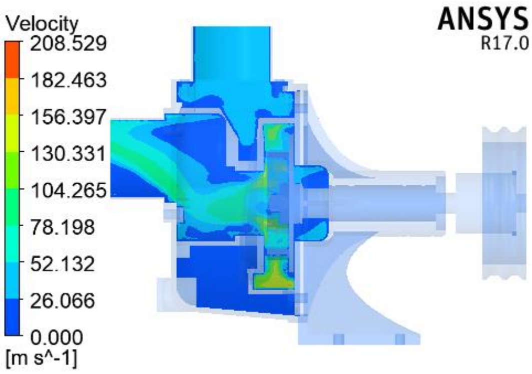

Figure 11. Speed results in Pump As Turbines (PATs)

- Impeller blade tip pressure

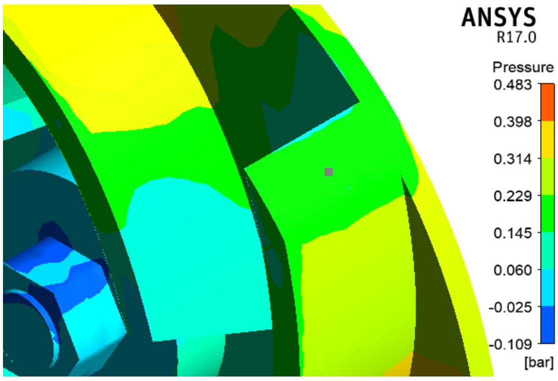

Figure 12. The results of the impeller tip pressure Pump As Turbines (PATs)

b) Inlet Pressure 14 psi (0.689 bar)

- Pressure

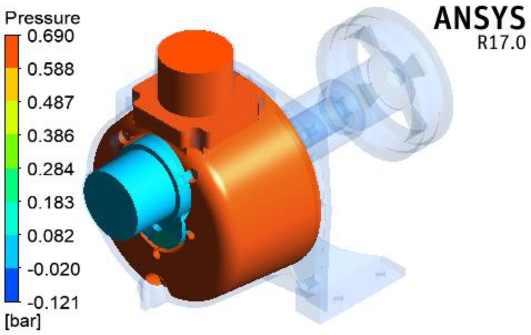

Figure 13. Pressure results on Pump As Turbines (PATs)

- Velocity

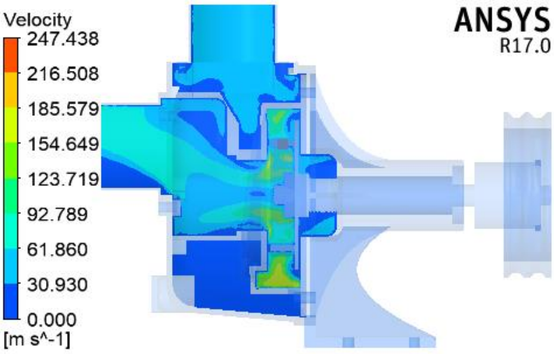

Figure 14. Speed results in Pump As Turbines (PATs)

- Impeller blade tip pressure

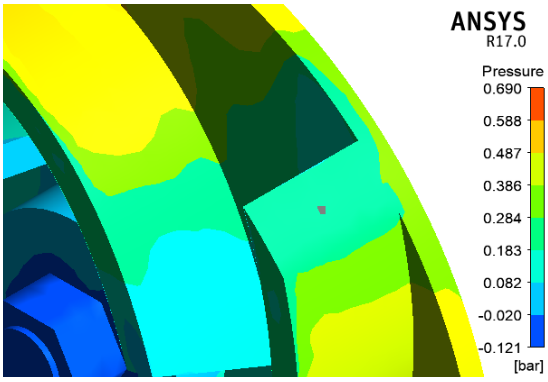

Figure 15. Results of impeller tip pressure Pump As Turbines (PATs)

c) Inlet Pressure 14 psi (0,965 bar)

- Pressure

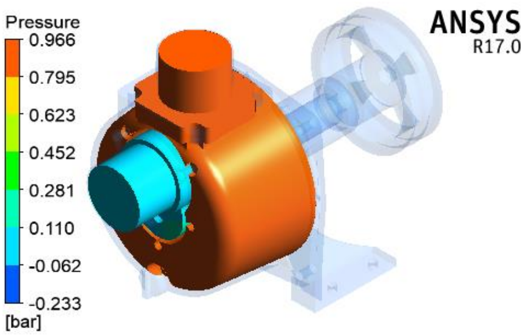

Figure 16. Pressure results on Pump As Turbines (PATs)

- Velocity

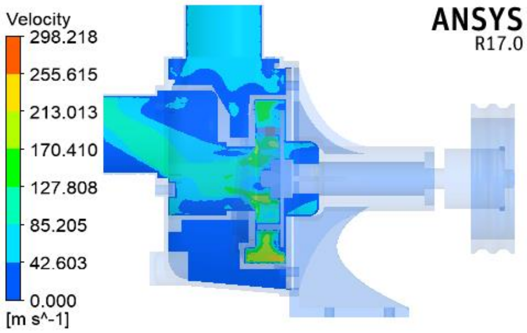

Figure 17. Speed results in Pump As Turbines (PATs)

- Impeller blade tip pressure

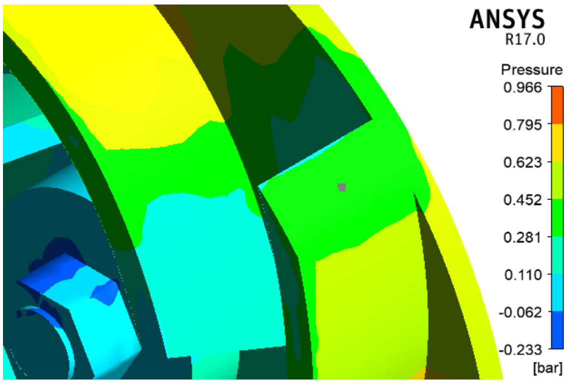

Figure 18. Results of Pump As Turbines (PATs) impeller tip pressure

The results of data analysis can be seen in table 5.

Table 5. Results of data analysis

P_{in} (psi)	P_{in} (bar)	P_{out} (bar)	V_{in} (m/s)	V_{out} (m/s)	P the tip of the impeller blade (bar)	n_2 PATs (rpm)
7	0,483	0,017	38,765	42,998	0,182	1207
10	0,689	0,021	47,428	50,981	0,250	1510
14	0,965	0,031	55,301	61,294	0,366	1928

Based on table 5, the results of data analysis of the effect of impeller tip pressure on Pump As Turbines (PATs) rotation can be seen in Figure 19.

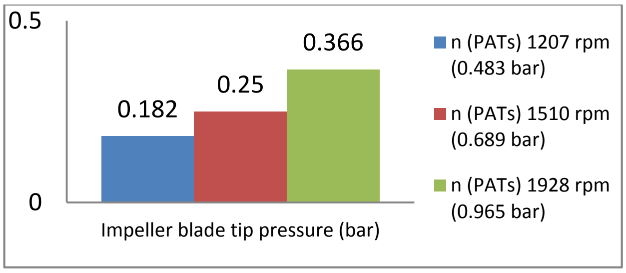

Figure 19. Results of the influence of impeller blade pressure on Pump As Turbines (PATs) rotation

Based on Figure 19, the results of data analysis of the influence of impeller blade pressure on Pump As Turbines (PATs) rotation are as follows:

- At the inlet pressure of 0.483 bar the impeller blade tip pressure is 0.182 bar, and the Pump As Turbines (PATs) 1207 rpm.
- At the inlet pressure of 0.689 bar, the impeller blade tip pressure is 0.250 bar, and the Pump As Turbines (PATs) rotation is 1510 rpm.
- At the inlet pressure of 0.965 bar, the impeller blade tip pressure is 0.366 bar, and the Pump As Turbines (PATs) rotation is 1928 rpm.
- The lowest blade tip pressure is in variations using 0.483 bar inlet pressure, which is 0.182 bar.
- The biggest blade tip pressure is found in variations using the inlet pressure of 0.965 bar which is 0.366 bar.
- The greater the pressure of the impeller blade tip, the greater the Pump As Turbines (PATs) rotation.

3.4. Data Validation

Data validation is to validate the results of data collection with the results of the analysis using Ansys fluent software. Data validation can be seen in table 6.

Table 6. Validation of data

Research result		Data collection results	Results of data analysis
#1	P_{in}	7 psi / 0.483 bar	7 psi / 0.483 bar
	P_{out}	NA	0.017 bar
	n_2 PATs	1207 rpm	1207 rpm
#2	P_{in}	7 psi / 0.689 bar	7 psi / 0,689 bar

	P_{out}	NA	0,021 bar
	n_2 PATs	1511 rpm	1511 rpm
#3	P_{in}	7 psi / 0.965 bar	7 psi / 0.689 bar
	P_{out}	NA	0.031 bar
	n_2 PATs	1928 rpm	1928 rpm

In the results of data collection, the estimated discharge pressure is 0-1 psi, due to the smallest scale of the measuring instrument is 2 psi, so the needle on the pressure gauge shows it remains at zero or not available (not available).

The results of data validation that have been done as shown in table 4.6 show that the results of data analysis are close to the results of data collection, so it can be concluded that the results of data analysis are following the data collected.

3.5. Stages of the Research Process

a. Effect of impeller blade tip angle on pressure

The research process is to look for the effect of the impeller blade tip angle on the pressure generated using the original 450 As Pumpbelt (PATs) impeller blade tip angle. This study also performed an optimization of the Pump As Turbines (PATs) impeller blade tip angle model 30° and 60°, and inlet pressures of 7 psi, 10 psi, and 14 psi (0.483 bar, 0.689 bar, and 0.965 bar). Figures 20-22 are the design angles of the Pump As Turbines (PATs) impeller blade angles of 30°, 45° and 60°.

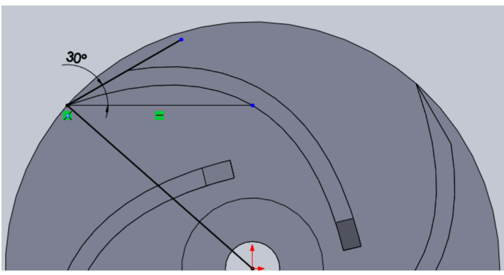

Figure 20. Impeller blade tip design 30°

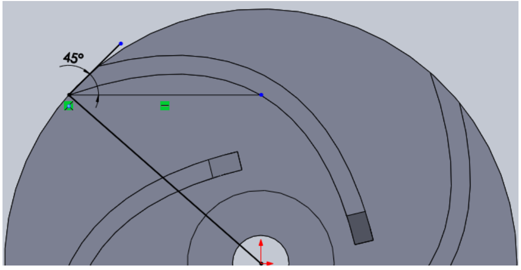

Figure 21. Impeller blade tip design angle 45°

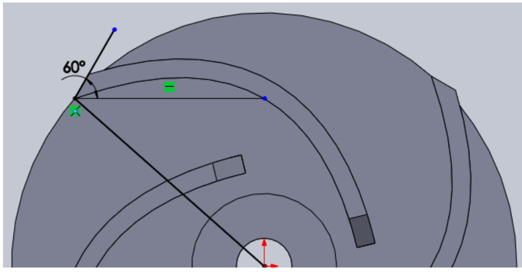

Figure 22. Impeller blade tip design Angle 60°

a) Result

The results of the research process to look for the influence of the impeller blade tip angle on the pressure generated using Ansys fluent software with the impeller blade tip design 300, 450, and 600. The research process is to see the pressure, pressure in the Pump As Turbines (PATs), speed and impeller blade tip pressure. The results of the research process looking for the influence of the impeller blade tip angle on pressure are as follows in table 7.

Table 7. Results of the research process the influence of the impeller blade tip angle on pressure

	P_{in} psi	P_{in} bar	P_{out} (bar)	V_{in} (m/s)	V_{out} (m/s)	P tip of the impeller blade (bar)
	7	0,483	0,018	38,361	43,855	0,251
30^0	10	0,689	0,028	46,002	53,593	0,355
	14	0,965	0,039	54,332	62,023	0,497
	7	0,483	0,017	38,765	42,998	0,182
45^0	10	0,689	0,021	47,428	50,981	0,250
	14	0,965	0,031	55,301	61,294	0,366
	7	0,483	0,017	39,883	43,613	0,123
60^0	10	0,689	0,024	47,562	51,150	0,182
	14	0,965	0,036	56,342	61,528	0,255

b) Discussion

Based on table 7, the results of the study of the influence of the impeller blade tip angle on the impeller blade tip pressure are as follows:

- The lowest impeller blade pressure is at the impeller blade tip angle 600 using 0.483 bar inlet pressure with the impeller blade pressure value 0.123 bar.
- The biggest impeller blade tip pressure is the impeller blade tip angle 300 using an inlet pressure of 0.965 bar with the impeller blade tip pressure value 0.497 bar.
- The greater the inlet pressure on Pump As Turbines (PATs) the greater the pressure on the tip of the impeller blade.

Based on the results of the research process that has been obtained, so it can be concluded that the design angle of the impeller Pump As Turbines (PATs) 30° is the most optimal from the original impeller tip angle 45° and 60°.

b. Optimal Pump As Turbine Designs (PATs)

Based on the results of the research process looking for the influence of the impeller blade angle to the pressure generated from the Pump As Turbines impeller blade angle (PATs) 30°, 45°, and 60°, the most optimal blade tip angle is to use the impeller blade tip design 30°.

In the research process to find the optimal design of Pump As Turbines (PATs) by changing the angle of the impeller tip of the Pump As Turbines (PATs) using an angle of 30° and approaching from an angle of 30°.

In this study, the tip angles of Pump As Turbines (PATs) 25° and 35° impeller blades, and inlet pressures of 7 psi, 10 psi, and 14 psi (0.483 bar, 0.689 bar, and 0.965 bar). Figure 3.21 - 3.23 is a picture of the design angle of the impeller Pump As Turbines (PATs) 25°, 30°, and 35°.

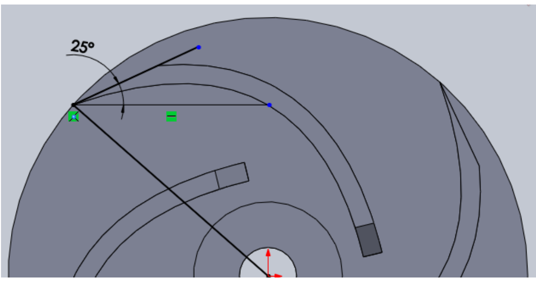

Figure 23. Impeller blade tip 25° design angle

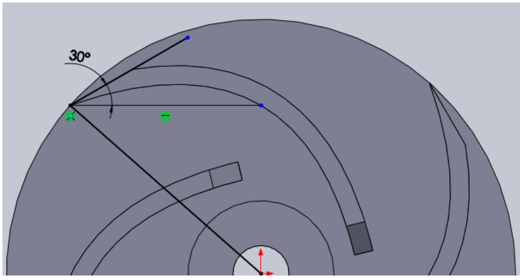

Figure 24. Impeller blade tip 30° design angle

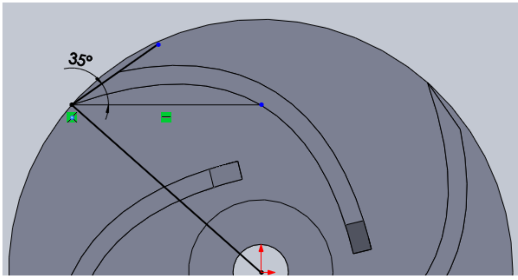

Figure 25. Impeller blade tip 35° design angle

a) Result

The results of the research process to find the optimal design of Pump As Turbines (PATs) by changing the angle of the tip of the impeller blade using Ansys fluent software is to see the pressure, speed, and pressure of the tip of the impeller blade. The results of the research process to find the optimal design Pump As Turbines (PATs) by changing the angle of the impeller blade are as follows in table 8.

Table 8. Results of optimal design of Pump As Turbines (PATs) by changing the angle of the tip of the impeller blade

	P_{in}		P_{out} (bar)	V_{in} (m/s)	V_{out} (m/s)	$P_{tip\ of\ the\ impeller\ blade}$ (bar)
	psi	bar				
	7	0.483	0.020	38.553	45.681	0.267
25^0	10	0.689	0.028	46.267	54.214	0.380
	14	0.965	0.039	54.464	64.875	0.543

	7	0.483	0.018	38.361	43.855	0.251
30^0	10	0,689	0.028	46.002	53.593	0.355
	14	0.965	0.039	54.332	62.023	0.497
	7	0.483	0.019	37.933	43.466	0.232
35^0	10	0.689	0.028	45.594	51.318	0.327
	14	0.965	0.039	53.948	60.442	0.457

b) Discussion

Based on table 8, the results of the study of the influence of the impeller blade tip angle with the impeller blade tip pressure are as follows:

- The lowest impeller blade pressure is at the impeller blade tip angle 350 using 0.483 bar inlet pressure with the impeller blade tip pressure value 0.232 bar.
- The largest impeller blade tip pressure is the impeller blade tip angle 250 using an inlet pressure of 0.965 bar with an impeller blade tip pressure value of 0.543 bar.
- The greater the inlet pressure on Pump As Turbines (PATs) the greater the pressure on the tip of the impeller blade.

The results of the study of the influence of impeller blade pressure on Pump As Turbines (PATs) rotation can be concluded that the smaller the angle of the impeller blade tip will produce greater impeller blade pressure, so the greater the Pump As Turbines (PATs) rotation. In this research, the impeller blade angle of 25°, 30°, and 35° optimal design of Pump As Turbines (PATs) is the impeller blade tip angle of 25°.

3.6. Results and Discussion

In this study is to analyze the flow in Pump As Turbines (PATs) using Ansys fluent software. In this research is to optimize by changing the design angle of the Pump As Turbines impeller blade angle (PATs) using the original impeller blade angle of 45°, 35°, 30°, and 25°, as well as 7 psi, 10 psi, and 14 psi (0.483 bar, 0.689 bar, and 0.965 bar).

The process of simulation or flow analysis in Pump As Turbines (PATs) using Ansys fluent software that has been done, then obtained research data that can be seen in table 9 and figure 26.

Table 9. Results of flow analysis research in Pump As Turbines (PATs)

	P_{in}		P_{out} (bar)	V_{in} (m/s)	V_{out} (m/s)	P the tip of the impeller blade (bar)
	psi	Bar				
	7	0.483	0.017	39.883	43.615	0.123
60^0	10	0.689	0.024	47.562	51.150	0.182
	14	0.965	0.036	56.342	61.528	0.225
	7	0.483	0.017	38.765	42.998	0.182
45^0	10	0.689	0.021	47.428	50.981	0.250
	14	0.965	0.031	55.301	61.294	0.366
	7	0.483	0.019	37.933	43.466	0.232
35^0	10	0.689	0.028	45.594	51.318	0.327
	14	0.965	0.039	53.948	60.442	0.457
	7	0.483	0.018	38.361	43.855	0.251
30^0	10	0.689	0.028	46.002	53.593	0.355
	14	0.965	0.039	54.332	62.023	0.497
	7	0.483	0.020	38.553	45.681	0.267
25^0	10	0.689	0.028	46.267	54.214	0.380
	14	0.965	0.039	54.464	64.875	0.543

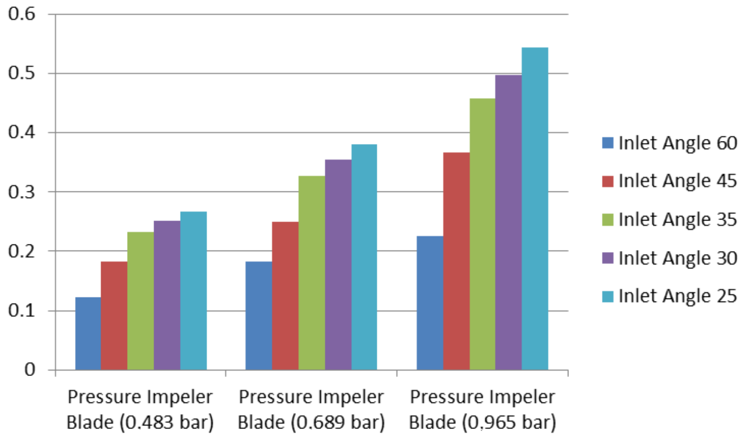

Figure 26. Effect of the impeller blade tip angle with the blade tip pressure

The process of simulation or flow analysis in Pump As Turbines (PATs) using Ansys fluent software that has been done, the research data obtained as shown in table 9. Discussion of research results is as follows:

a. At the 7 psi (0.483 bar) inlet pressure using the original Pump As Turbines (PATs) impeller blade tip angle design, the results of the analysis in Pump As Turbines (PATs) exit speed 42.998 m / s, 0.017 bar exit pressure, and end pressure impeller blade 0.182 bar.

b. Using the impeller blade angle of the Pump As Turbines (PATs) 60°, 45°, 35°, 30°, and 25°, the lowest impeller blade pressure at the impeller blade tip angle 60° uses 7 psi

(0.483 bar) inlet pressure with an end pressure value impeller blade 0.123 bar.

c. The biggest impeller blade pressure is the impeller blade tip angle 250 using 14 psi (0.965 bar) inlet pressure with impeller blade pressure value 0.543 bar.
d. The smaller the angle of the tip of the impeller blade on the Pump As Turbines (PATs), the greater the pressure of the tip of the impeller blade.
e. Based on the results of the impeller blade pressure obtained, the optimal design of Pump As Turbines (PATs) is to use the impeller blade tip angle 25°.
f. The design angle of the impeller blade 25° is a critical angle from Pump As Turbines (PATs), because if it uses an impeller design less than 25° it will run out of the impeller blade shape so that it can affect the resulting rotation.
g. The design angle of the impeller Pump As Turbines (PATs) 25° uses 14 psi (0.965 bar) inlet pressure, the results of the analysis in Pump As Turbines (PATs) namely:
    - Incoming speed of 54.464 m / s and exit speed of 64.875 m / s means that the results of the speed at the time of exit will be faster due to the impeller rotation.
    - Pressure in the Pump As Turbines (PATs) is around 0.965 bar while when entering the impeller the pressure becomes 0.095-0.841 bar, due to the rotation of the Pump As Turbines (PATs) impeller the pressure towards the outflow becomes around 0.039 bar.

4. CONCLUSION

Design the impeller blade angle of the Pump As Turbines (PATs) 60°, 45°, 35°, 30°, and 25°, the lowest impeller blade pressure at the impeller blade tip angle 60° using 7 psi (0.483 bar) inlet pressure with a pressure tip pressure value impeller 0.123 bar and the largest is the tip angle of the impeller 25° using 14 psi (0.965 bar) inlet pressure with impeller tip pressure values 0.543 bar. Based on the results of the impeller blade tip pressure obtained, the optimal design of Pump As Turbines (PATs) is to use the impeller blade tip angle 25°. The impeller blade tip angle design 25° is a critical angle from Pump As Turbines (PATs) because if you use the impeller design it is less from 25° it will run out of impeller blade shape so that it can affect the resulting rotation. Design the tip angle of the impeller Pump As Turbines (PATs) 25° using 14 psi (0.965 bar) inlet pressure, the results of the analysis in Pump As Turbines (PATs). Inlet speed of 54.464 m/s and Outlet speed of 64.875 m/s means that the results of the speed at the time of exit will be faster due to the impeller rotation. Pressure in the Pump As Turbines (PATs) is around 0.965 bar while when entering the impeller the pressure becomes 0.095-0.841 bar, due to the rotation of the Pump As Turbines (PATs) impeller the pressure towards the outflow becomes around 0.039 bar.

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