The 5th International Conference on Innovations in Social Sciences Education and Engineering
(ICoISSEE-5)
Bandung, Indonesia, July, 26th, 2025

COMPARATIVE STUDY OF BLADE ANGLE AND NUMBER ON THE ROTATIONAL PERFORMANCE OF A PELTON TURBINE

[1]Fajri Yatul Syaputra,*[2]Desmarita Leni,[3]Muchlisinalahuddin

[1,2,3]Mechanical Engineering, Engineering, Universitas Muhammadiyah Sumatera Barat, Indonesia

Author's email:
[1]fajrisyaputra050400@yahoo.com; [2]desmaritaleni@gmail.com
[3]muchlisinalahuddin.umsumbar@gmail.com

**Corresponding author:fajrisyaputra050400@gmail.com*

Abstract. *The Pelton turbine is a type of impulse turbine ideal for hydroelectric power plants with high head and low discharge. However, the energy conversion efficiency of this turbine is greatly influenced by the blade design, especially the angle and number of blades. The main problem often found is the suboptimal pressure distribution and rotational stability due to variations in blade geometry. This study aims to analyze the effect of variations in blade angle (15°, 20°, 25°) and number of blades (18, 20, 24) on the rotational performance of a laboratory-scale Pelton turbine. The method used is Computational Fluid Dynamics (CFD) simulation to evaluate pressure, fluid velocity, force, and torque in each configuration. The results show that the combination of a 15° angle with 18 blades produces the highest fluid acceleration, while a 20° angle with 24 blades provides the best pressure distribution and stability. This study recommends a design according to power and operational requirements.*

Keywords: *Blade Angle, CFD, Number of Blades, Pelton Turbine, Rotational Performance*

1. INTRODUCTION

Hydroelectric power plants (PLTA) are a renewable energy technology with significant potential to meet electricity needs, particularly in remote areas not yet connected to the national electricity grid. One type of turbine widely used in small-scale hydroelectric power systems with high head and low discharge is the Pelton turbine. These characteristics make the Pelton turbine highly suitable for applications in mountainous areas or areas with small rivers that have high water pressure but limited flow volume. (Hidayat, 2019).

Pelton turbines operate on the principle of impulse, where the potential energy of water is converted into kinetic energy through nozzles and directed as a high-speed water jet that strikes the turbine's blades (bucket) (Leni et al., 2023). The effectiveness of energy transfer from the water jet to the blades significantly determines the turbine's performance. In this context, turbine blade design, particularly its blade angle and number of blades, plays a crucial role. The blade angle can affect the impact pattern and water flow from the blades, while the number of blades can affect the continuity of the thrust acting on the turbine runner (Assyary et al., 2022).

Several previous studies have shown that the geometric parameters of a Pelton turbine, particularly the blade angle and number of blades, can significantly impact the turbine's rotational speed (RPM) and efficiency. Too small or too large a blade angle can result in splash and backflow, which can reduce energy efficiency. Likewise, too few blades can create uneven thrust, while too many blades can increase drag and friction, thus reducing turbine performance (Dewangga et al., 2022).

Currently, in the Mechanical Engineering Laboratory of the University of Muhammadiyah West Sumatra, a mini-Pelton turbine is available that can be used as a medium for practical work and research. The existence of this tool provides an opportunity for researchers to analyze the effect of variations in the angle and number of blades on the performance of the Pelton turbine. Several problems that need to be studied in this research include the effect of variations in the blade angle on the performance of the turbine rotation, the effect of the number of blades on the performance of the turbine rotation, identifying the combination of angles and number of blades that can produce the most optimal turbine rotation tested. (I as the level of difference in Pelton turbine performance from each variation of angle and number of blades tested (Pratama et al., 2021).

This study aims to address these issues by conducting a direct experimental analysis of an available mini-Pelton turbine. The results are expected to contribute scientifically to the development of small-scale hydropower generation technology and serve as a reference for developing more efficient turbine designs and for practical applications in Mechanical Engineering, particularly in the context of renewable energy conversion technology (Kusnadi et al., 2018).

2. LITERATURE REVIEW

2.1 Water Turbines and Their Basic Working Principles

A water turbine is a mechanical device that converts the potential and kinetic energy of water into rotational mechanical energy, which can then be used to drive an electric generator. The use of water turbines as an energy conversion technology has been widely applied in various hydroelectric power generation (PLTA) systems, particularly in areas with high water flow potential, both in terms of discharge and height (head) (Arwizet et al., 2023). In general, water turbines can be classified based on their fluid flow patterns and conversion methods, including Pelton turbines, Franci’s turbines, and Kaplan turbines, each of which has different operational characteristics according to the head and water discharge values. (Basori et al., 2016).

2.2 Pelton Turbine

The Pelton turbine is an impulse turbine designed for areas with high head and low water discharge. Its working principle relies on the kinetic energy of a water jet directed from a nozzle to the double-bowl-shaped turbine blades. The impulse force of the water jet striking the turbine blades generates rotational momentum in the runner. The main components of a Pelton turbine include a runner (equipped with blades), a nozzle, a shaft, and a casing, each of which plays a role in optimizing the energy conversion process from water to mechanical energy (Susanto et al., 2019).

2.3 Turbine Blades and Their Functions

The blades, or buckets, are vital components of a Pelton turbine, receiving energy from the water jet and converting that momentum into rotary work. Turbine efficiency is greatly influenced by the design of the blades, including their angle and number. The blade angle determines the turbine's ability to deflect the water flow nearly 180°, while the number of blades determines the smoothness of the energy received from the water jet. Selecting the correct blade angle and number can minimize flow disturbances and maximize turbine efficiency (Sidik et al., 2018).

2.4 Pelton Turbine Working Principle

Pelton turbines work based on the law of conservation of momentum, where high-speed water from the nozzle hits the blades, resulting in a change in momentum that provides a rotating force on the runner. (Ardika Tommy Saputra et al., 2020). Equation (2.1) can be used to calculate the resulting force:

$$\mathrm{F} = \mathrm{m}^{\cdot}(\mathrm{V}_{\mathrm{in}} - \mathrm{V}_{\mathrm{out}})$$

With:
$m^{\cdot}$: mass flow rate,
Vin : entry speed
Vout : exit speed

2.5 Turbine Performance

Turbine performance can be measured by its rotational speed (RPM), a key parameter in evaluating the efficiency of converting energy from water to mechanical energy. Turbine rotation is influenced by the shape, number, and angle of its blades, as well as the design's suitability to the water flow and head. Selecting the optimal blade configuration and number of blades can maximize the turbine's rotational speed and efficiency (Nandar et al., 2023).

2.6 Types of Water Turbines

Water turbines can be classified into two main categories, namely impulse turbines and reaction turbines, based on their working mechanism and the form of water energy utilization.

1. Impulse Turbine

Impulse turbines utilize the kinetic energy of water, which is completely converted from potential energy before it hits the turbine blades. The water stream exits the nozzle at high speed and strikes the turbine blades, which are exposed to the atmosphere, generating rotation by exploiting the change in momentum (Girsang et al., 2018).

2. Reaction Turbine

Unlike impulse turbines, reaction turbines harness energy from water, which is partly kinetic and partly pressure. The water flow is pressurized as it enters the turbine, causing energy changes within the blades. The water flow is controlled by the casing and draft tube to maintain turbine efficiency, making it ideal for areas with low to moderate head and high-water discharge (Rachman & Goeritno, 2024).

2.7 Main Components of a Pelton Turbine

The Pelton turbine consists of several key components, namely:

a) Nozzle, which functions to convert water pressure energy into kinetic energy in the form of a high-speed jet.
b) Bucket, to receive and deflect water jets up to almost 180°.
c) Runner, as a place to mount the blades which rotate due to the force of the water jet.
d) Shaft, to transmit mechanical energy from the runner to a generator or other system.
e) Casing, sebaprotective and wastewater reservoir from the turbine.

Each of these components contributes significantly to the performance and efficiency of the Pelton turbine, particularly in the context of designing both laboratory-scale and hydropower-scale turbines.

3. RESEARCH METHODS

This research is experimental research with a simulation and laboratory testing approach, which was carried out at the Energy Conversion Laboratory and Mechanical Engineering Workshop, Mechanical Engineering Study Program, Faculty of Engineering, Muhammadiyah University of West Sumatra. This location was chosen because it is equipped with adequate facilities and equipment to support the design, assembly, and testing of a laboratory-scale Pelton turbine. This research took place from May 2025 to September 2025, covering the stages of literature study, turbine model design, blade and runner manufacturing process, test equipment installation, experiment implementation, data processing, and article preparation.

The stages of this research are presented in the flow diagram Figure 1.

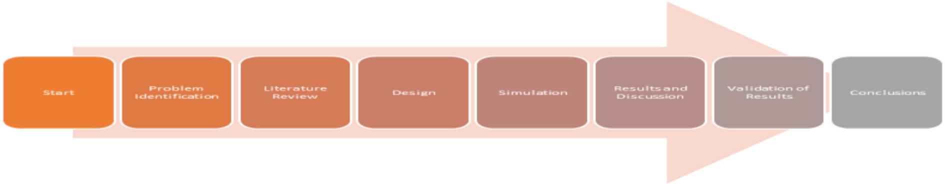

Figure 1. Flow chart (Source: Authors, 2025)

3.1 Start

The research began with an initial stage to determine the context and objectives of the research, namely to examine the effect of variations in the angle and number of Pelton turbine blades on the turbine rotation performance.

3.2 Identification of problems

At this stage, problems related to the efficiency and performance of the Pelton turbine are identified, particularly those related to the blade design (angle and number of blades) whose specific effects on the turbine rotation and efficiency are not yet known.

3.3 Literature Study

The literature review in this study was conducted to explore various aspects relevant to the design and performance of the Pelton turbine. This study includes an analysis of the working principles of the Pelton turbine, including the mechanism of converting potential energy of water into kinetic energy and the distribution of fluid flow around the blades. Furthermore, special attention is paid to the influence of blade geometry, such as the angle and number of blades, on pressure distribution, fluid acceleration, and rotational stability. Relevant previous research was also reviewed in depth to determine the main parameters to be used in the simulation, so that the research design can refer to a strong theoretical basis and be in accordance with real operational conditions.

3.4 Design

The design phase consists of creating a Pelton turbine model with varying angles and number of blades according to specified parameters. This model is designed using CAD software (such as SolidWorks) and prepared for the simulation phase.

3.5 Simulation

Numerical simulations were performed using Solidworks 2025 software to analyze fluid flow behavior in a Pelton turbine model. The simulation procedure consists of several main stages as follows:

1) Meshes are generated at high resolution to ensure numerical accuracy in discretizing the fluid domain. A fine mesh structure is applied to critical areas, such as around blades, to accurately capture flow gradients.

2) Determining Boundary Conditions

Boundary conditions are determined by setting the inlet mass flow as the input parameter and the outlet pressure as the downstream boundary condition. These parameters are adjusted based on the turbine fluid flow characteristic standards.

3) Solver Settings

A pressure-based solver is used to numerically solve the Navier-Stokes equations. The solution and convergence schemes are chosen to support stability and computational efficiency in transient or steady-state simulations.

4) Simulation Output Extraction

The simulation results include numerical data related to static, total, and dynamic pressures, fluid velocities, as well as forces in the X, Y, and Z axes and torques about the main rotational axes. This data is used to evaluate the aerodynamic performance and mechanical efficiency of the system.

3.6 Results and Discussion

Simulation results were systematically collected and recorded for each variation in blade angle and number. Data collection was performed at least three times to ensure accuracy and reliability.

The collected data was then analyzed to compare the average rotational speeds of each configuration. This analysis was presented graphically to facilitate the identification of trend patterns and the determination of the design with the highest performance.

3.7 Validation and Interpretation of Results

Simulation and analysis results are compared with theoretical foundations from literature studies to assess the suitability of the obtained work patterns. Interpretations are conducted to explain the technical phenomena that occur, including why certain blade angle and number configurations can provide higher performance values than others.

3.8 Conclusion

At the final stage, the conclusion is based on the analysis and evaluation conducted. This conclusion answers the research problem formulation, includes recommendations for the most optimal design parameters (angle and number of blades), and provides direction for further development or testing, such as experimental testing or assessing the effects of other parameters, including inlet pressure and water flow.

4. RESULTS AND DISCUSSION

4.1 Results

This research, entitled "Comparative Study of Blade Angle and Number on the Rotational Performance of a Pelton Turbine," aims to evaluate the effect of variations in blade angle and number of blades on the rotational performance of a Pelton turbine. In the initial stage, this research began by designing a Pelton turbine model using CAD software, taking into account geometric dimensions and fluid characteristics appropriate to operational conditions. The developed model was then analyzed through Computational Fluid Dynamics (CFD) simulations to study the distribution of pressure, flow velocity, force, and torque generated at various variations in blade angle and number of blades. This simulation was also conducted to ensure numerical convergence and flow stability in each configuration. The results of the analysis are presented in tabular form and visualizations to facilitate quantitative and qualitative comparison of the performance of each variation.

1. 15° angle

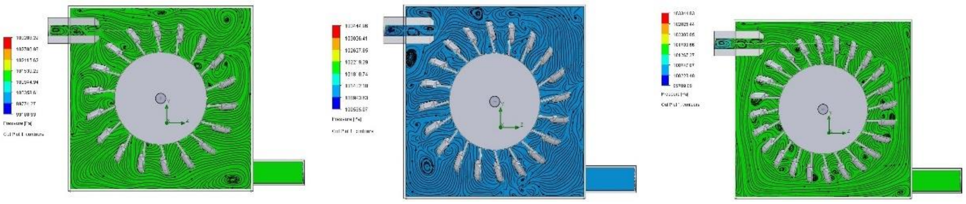
(a) (b) (c)

Figure 2. Platen Tube Blade with an angle of 15°(a) Blade 18 (b) Blade 20 (c) Blade 24

The results of the comparison of the performance parameters of the 15° Pelton turbine with variations in the number of blades (18, 20, and 24 blades) are shown in Table 1. The table contains the minimum and maximum static pressure values, maximum total pressure, maximum dynamic pressure, maximum flow velocity, dominant force on the Y axis, and maximum torque on the X axis.

Table 1. Simulation results with an angle of 15°

Parameter	18 tablespoons	20 tablespoons	24 tablespoons
Minimum Static Pressure (Pa)	100,905.70	100,701.90	100,905.40
Maximum Static Pressure (Pa)	103,286.30	103,445.00	103,344.80

Maximum Total Pressure (Pa)	103,546.40	103,702.00	103,592.10
Maximum Dynamic Pressure (Pa)	1168,377	1125,456	1151,779
Maximum Flow Velocity (m/s)	1,530512	1,502136	1,519601
Y-Axis Dominant Force (N)	0.027724	0.028187	0.02763
X-Axis Maximum Torque (N·m)	0.003052	0.003393	0.003042

From the comparison of the 3 variations, it was found that the 18-blade configuration produced the highest maximum dynamic pressure of 1168.377 Pa and a slightly higher maximum total pressure compared to the other configurations. The 24-blade configuration showed the highest maximum flow velocity of 1.519601 m/s. Meanwhile, the 20-blade configuration produced a dominant Y-axis force and a larger X-axis maximum torque with values of 0.028187 N and 0.003393 N m, respectively. Overall, each variation in the number of blades has advantages in certain parameters, but the 20-blade configuration tends to be more balanced in the force and torque produced.

2. 20° angle

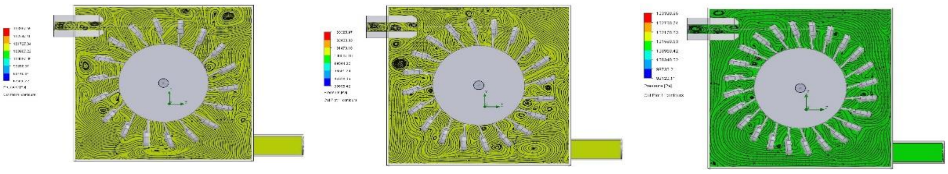
(a) (b) (b)

Figure 3. Platen Tube Blade with an angle of 20°(a) Blade 18 (b) Blade 20 (c) Blade 24

Comparison of the performance parameters of the 20° angle Pelton turbine with various numbers of blades (18, 20, and 24 blades) is presented in Table 2. This table displays the minimum and maximum static pressure data, maximum total pressure, maximum dynamic pressure, maximum flow velocity, dominant force on the Y axis, and maximum torque on the X axis.

Table 2. Simulation results with an angle of 20°

Parameter	18 tablespoons	20 tablespoons	24 tablespoons
Minimum Static Pressure (Pa)	100,883.10	100,885.80	100,063.50
Maximum Static Pressure (Pa)	103,367.60	103,396.00	103,390.10
Maximum Total Pressure (Pa)	103,603.20	103,642.10	103,613.10
Maximum Dynamic Pressure (Pa)	1,219.20	1,117.39	1,107.05
Maximum Flow Velocity (m/s)	1,563443	1.496744	1.489805
Y-Axis Dominant Force (N)	0.02646	0.028305	0.028587
X-Axis Maximum Torque (N·m)	0.003282	0.003318	0.003216

Simulation results show that variations in the number of blades in a Pelton turbine significantly impact performance parameters. The 18-blade configuration produces the highest maximum dynamic pressure of 1,219.20 Pa and a maximum flow velocity of 1.563443 m/s, reflecting better flow acceleration and fluid kinetic energy. Meanwhile, the 20-blade configuration records the highest maximum total pressure of 103,642.10 Pa and a maximum torque on the X-axis of 0.003318 N m, indicating good mechanical stability. On the other hand, the 24-blade configuration produces the highest dominant force on the Y-axis of 0.028587 N, indicating optimal fluid thrust despite slightly lower dynamic velocity and pressure values compared to the other configurations. Overall, each configuration exhibits its own advantages in certain parameters, with 18 blades excelling in flow acceleration, 20 blades in stability, and 24 blades in fluid thrust.

3. 25° angle

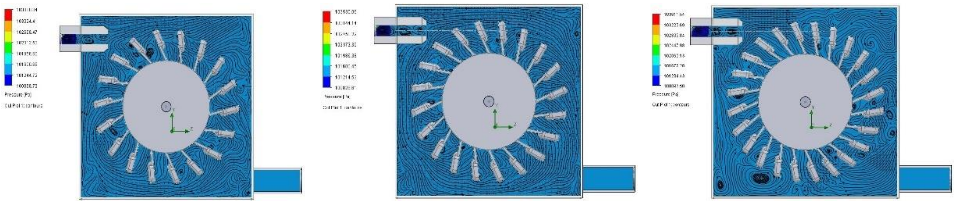
(a) (b) (c)

Figure 5. Platen tube blade with an angle of 25° (a) Blade 18 (b) Blade 20 (c) Blade 24

Based on CFD simulation at nozzle tilt angle of 35°with 3 variations of pressure applied as at an angle of 15°and 30°the comparative results are obtained as shown in Table 3.

CONCLUSION

A The results of the comparison of the performance parameters of the 25° Pelton turbine with variations in the number of blades (18, 20, and 24 blades) are shown in Table 3. The table contains the minimum and maximum static pressure values, maximum total pressure, maximum dynamic pressure, maximum flow velocity, dominant force on the Y axis, and maximum torque on the X axis.

Table 3. Simulation results with an angle of 20°

Parameter	18 tablespoons	20 tablespoons	24 tablespoons
Minimum Static Pressure (Pa)	100,896	100,828.60	100,779
Mean Static Pressure (Pa)	100,468	100,576	100,779
Maximum Static Pressure (Pa)	103,380	103,530.10	103,743
Maximum Total Pressure (Pa)	103,743	103,743	103,853.30
Maximum Dynamic Pressure (Pa)	1,093.37	1,157.82	1,213.02
Maximum Speed (m/s)	1,480566	1.523579	1,558
Y-Axis Dominant Force (N)	0.02761	0.036207	0.034
X-Axis Maximum Torque (N·m)	0.002993	0.033891	0.004986

The CFD simulation results at a blade angle of 25° show significant performance differences between the 18, 20, and 24 blade configurations. The 18-blade configuration produces a maximum dynamic pressure of 1,093.366 Pa with a maximum flow velocity of 1.480566 m/s, as well as a dominant Y-axis force of 0.02761 N and a maximum torque of 0.002993 N m, which indicates good fluid acceleration but relatively small torsional moment. In the 20-blade configuration, the dynamic pressure increases to 1,157.817 Pa with a maximum flow velocity of 1.523579 m/s. The dominant Y-axis force of 0.036207 N and a maximum torque of 0.033891 N m indicate increased fluid thrust and better rotational stability compared to the 18-blade configuration. Meanwhile, the 24-blade configuration produces the most optimal performance, with the highest maximum dynamic pressure of 1,213,020 Pa and a maximum speed of 1,558 m/s. The dominant Y-axis force of 0.034 N and a maximum torque of 0.004986 N m demonstrate the system's ability to produce more stable thrust and torsional moments. Overall, although each configuration has certain advantages, the 24-blade configuration shows a more even pressure distribution, more significant fluid acceleration, and superior mechanical stability.

4.2 Discussion

Based on the results of Computational Fluid Dynamics (CFD) simulations, the effect of variations in blade angle and number of blades on the rotational performance of the Pelton turbine can be analyzed in detail and the results are as below.

4.2.1 The Effect of Blade Angle Variations on Pelton Turbine Performance

The blade angle is a crucial factor influencing the fluid flow pattern along the blade profile. At a 15° angle, the simulation results show a stable pressure distribution from the inlet to the outlet of the system. The 18-blade configuration recorded a maximum dynamic pressure of 1,168.377 Pa and a maximum fluid velocity of 1.530512 m/s. These values indicate significant fluid acceleration, resulting in higher kinetic energy. The dominant force on the Y-axis is also well maintained, while the maximum torque on the X-axis is at a sufficient level to support rotational stability.

In contrast to the 15° angle, the 20° angle shows a slight decrease in maximum dynamic pressure to 1,219.198 Pa, but with a higher maximum fluid velocity of 1.563443 m/s. The pressure distribution at this angle is more even, thus reducing the potential for turbulence and the risk of cavitation. System stability is increased with a dominant force on the Y axis of 0.028587 N in the 24-blade configuration. This indicates that the 20° angle is more suitable for continuous operation with stable flow requirements.

At an angle of 25°, system performance again improves, especially in the 24-blade configuration. The maximum dynamic pressure reaches 1,213,020 Pa with a maximum fluid velocity of 1,558 m/s. The resulting thrust on the Y axis is 0.034 N and the maximum torque is 0.004986 N m, indicating better rotational stability. This angle is able to facilitate a more optimal distribution of fluid energy, although the fluid acceleration is slightly lower than the 15° angle.

4.2.2 The Effect of Variations in the Number of Blades on Pelton Turbine Performance

The number of blades in a Pelton turbine significantly affects energy efficiency and flow stability. The 18-blade configuration produces higher fluid acceleration with a maximum dynamic pressure of 1,168.377 Pa at an angle of 15°, but the pressure distribution tends to be sharper, increasing the risk of local turbulence. The 20-blade configuration shows a good balance between acceleration and stability with a maximum dynamic pressure of 1,117.391 Pa and a maximum fluid velocity of 1,496744 m/s. The more even pressure distribution indicates that this number of blades is able to reduce flow disturbances.

Meanwhile, the 24-blade configuration produces the most stable pressure distribution. Although the fluid acceleration is slightly lower (maximum dynamic pressure of 1,107.053 Pa at a 15° angle), this configuration has a dominant force on the Y axis of 0.028587 N and a maximum torque that supports rotational stability. The denser blades also allow for a larger fluid contact area, allowing for maximum utilization of fluid energy.

4.2.3 Optimal Combination of Angle and Number of Blades

The simulation results show that the combination of a 15° blade angle with 18 blades provides the highest fluid acceleration with a maximum dynamic pressure of 1,168.377 Pa and a maximum fluid velocity of 1.530512 m/s. This combination is very suitable for applications that require large power in a short time. On the other hand, the combination of a 20° angle with 24 blades shows better pressure distribution stability and optimal thrust. The maximum total pressure reaches 103,613.1 Pa with a dominant force on the Y axis of 0.028587 N, making it an ideal choice for long-term operations with stable flow requirements and minimal turbulence.

4.2.4 Design Implications of Pelton Turbine

The performance differences between each blade angle and number combination provide important insights into Pelton turbine design. A smaller blade angle with fewer blades provides high flow acceleration, while a larger blade angle with more blades offers better energy distribution stability. Therefore, selecting the optimal configuration must be tailored to the specific requirements, whether for applications with significant load fluctuations or for continuous operation with stable flow.

4.2.5 Validation of CFD Simulation Results on Pelton Turbine

Your CFD simulation results are consistent with the findings of Židonis & Aggidis (2019), who showed that reducing the number of blades can increase the efficiency of a Pelton turbine, leading to high fluid acceleration but impacting the stability of the pressure distribution when fewer blades are used. The findings of Arifin et al. (2022) also support this, where the fewest blade configuration produces the best fluid velocity despite lower pressure, aligning with your observation that the 15°–18 blade angle combination provides maximum fluid acceleration. Furthermore, the parametric study by Illuchi N°2 (2023) reported improved efficiency and better pressure distribution when blade angle and blade geometry were optimized, matching your conclusion that the 20°–24 blade angle combination produces the most stable pressure and torque distribution. These three studies strengthen the validity of the CFD model and support the recommendation of the optimal configuration based on specific operational requirements.

CONCLUSION

The results of this study indicate that variations in the blade angle and number of blades in a Pelton turbine significantly affect turbine performance, especially in the aspects of fluid acceleration, pressure distribution, and rotational stability. A blade angle of 15° produces the highest fluid acceleration and kinetic energy, with a maximum dynamic pressure of 1168.377 Pa, making it optimal for applications that require large power in a short time. In contrast, a blade angle of 20° shows better pressure distribution stability, although the maximum dynamic pressure is slightly lower at 1,219.198 Pa, making it more suitable for long-term applications with operational stability requirements.

The number of blades also plays a crucial role in fluid energy efficiency and rotational stability. A configuration with 18 blades produces optimal fluid acceleration, while a configuration with 24 blades provides better pressure stability. A 15° angle with 18 blades has been shown to provide maximum fluid acceleration, while a 20° angle with 24 blades provides superior pressure stability.

These results confirm that the selection of blade angle and number of blades must be tailored to the operational requirements of the Pelton turbine. A small angle with a moderate number of blades is more suitable for applications that prioritize high fluid acceleration, while a large angle with a larger number of blades is more ideal for pressure stability in long-term operation. These findings provide an important contribution to the optimization of Pelton turbine design for various operational requirements.

REFERENCES

Aggidis, G., & Židonis, A. (2023). Development of a Novel High Head Impulse Hydro Turbine. Sustainability, 16(1), 253. https://doi.org/10.3390/su16010253

Ardika Tommy Saputra, IM, Jasa, L., & Arta Wijaya, IW (2020). THE EFFECT OF WATER PRESSURE AND NOZZLE ANGLE ON OUTPUT CHARACTERISTICS OF A PROTOTYPE OF A MHP WITH A PELTON TURBINE. SPEKTRUM Journal, 7(4), 17. https://doi.org/10.24843/SPEKTRUM.2020.v07.i04.p3

Arwizet, K., Leni, D., Aprilman, D., Adriansyah, A., & Chadry, R. (2023). Performance Analysis of Hydrokinetic Turbine Using Shroud Ratio Comparison under Yaw Misalignment Condition. INVOTEK: Journal of Vocational and Technology Innovation, 23(1), 21-32.

Assyary, NS, Rijanto, A., & Dyah, AI (2022). Analysis of the Effect of the Number of Microhydro Turbine Blades on the Output Power Produced by a Permanent Generator. Majamecha, 4(2), 87–95. https://doi.org/10.36815/majamecha.v4i2.1322

Basori, Wismanto Setyadi, & Ferdiana, R. (2016). ANALYSIS OF WATER TURBINE PERFORMANCE IN A 70 MW HYDROPOWER PLANT (PLTA). Journal of Energy Conversion and Manufacturing, 3(3), 131–134. https://doi.org/10.21009/JKEM.3.3.3

Dewangga, YA, Kholis, N., Baskoro, F., & Haryudo, SI (2022). The Effect of the Number of Water Turbine Blades on the Performance of Hydroelectric Power Generators. JOURNAL OF ELECTRICAL ENGINEERING, 11(1), 71–76. https://doi.org/10.26740/jte.v11n1.p71-76

Felix Adityo Rachman & Arief Goeritno. (2024). Construction of a Crossflow Type Water Turbine as a Single-Phase Generator Driver in a Pico-Hydro Power Plant. JuTEkS (Jurnal Teknik Elektro dan Sains), 10(2), 62–67. https://doi.org/10.32832/juteks.v10i2.15899

Girsang, DA, Gultom, S., Andianto P., Mahadi, & Sembiring, PG (2018). PERFORMANCE TEST OF THE EFFECT OF VORTEX HEAD VARIATION ON VORTEX TURBINE PERFORMANCE. DYNAMICS, 6(3), 11. https://doi.org/10.32734/dinamis.v6i3.7139

Hidayat, W. (2019). Working Principles and Components of Hydroelectric Power Plants (PLTA). INA-Rxiv. https://doi.org/10.31227/osf.io/drv58

Ibarra, GA, Ladino, JA, Larrahondo, F.J., & Rodriguez, S.A. (2024). Optimization and reconstruction of Pelton buckets based on statistical techniques, artificial neural networks and CFD modeling. Renewable Energy, 231, Article 120933. https://doi.org/10.1016/j.renene.2024.120933

Kusnadi, K., Mulyono, A., Pakki, G., & Gunarko, G. (2018). DESIGN AND PERFORMANCE TESTING OF A MICROHYDROGENIC-SCALE KAPLAN-TYPE WATER TURBINE. Turbo: Journal of Mechanical Engineering Study Program, 7(2). https://doi.org/10.24127/trb.v7i2.817

Leni, D., & Kesuma, DS (2023). Performance Analysis of Hydrokinetic Turbine with Diffuser Casing in Yaw Misalignment Condition Based on Water Flow Velocity Variation. Journal of Materials, Manufacturing and Energy Engineering, 6(2), 203-210.

Merino, CAI, Ceballos Zuluaga, JM, Patiño, ID, & Morales Rojas, AD (2023). Fluiddynamic simulations for assessment of dimensioning methodologies of Pelton turbine buckets considering the initial torque overcoming. Journal of Applied and Computational Mechanics, 9(4), 1–13. https://doi.org/10.22055/jacm.2023.42512.3935

Nandar, A., Gunawan, G., Suanggana, D., & Djafar, A. (2023). EXPERIMENTAL STUDY OF THE EFFECT OF HEAD ON THE PERFORMANCE OF A THREE-BLADE ARCHIMEDES SCREW TURBINE. Scientific Journal of Technology and Engineering, 28(2), 159–170. https://doi.org/10.35760/tr.2023.v28i2.5275

Pratama, PA, Malyadi, M., & Wicaksono, YA (2021). EXPERIMENTAL STUDY OF VARIATIONS OF BLADE SHAPE AND ANGLE ON PELTON TURBINE PERFORMANCE. AutoMech: Journal of Mechanical Engineering, 1(01). https://doi.org/10.24269/jtm.v1i01.4254

Sidik, HP, Gunarto, G., & Sarwono, E. (2018). ANALYSIS OF POWER EFFICIENCY IMPROVEMENT IN LABORATORY-SCALE PELTON TYPE TURBINE BLADES. Suara Teknik: Jurnal Ilmiah, 9(2). https://doi.org/10.29406/stek.v9i2.1535

Susanto, L., Priangkoso, T., & Darmanto, D. (2019). DESIGN OF A 1 KW CAPACITY PICO HYDRO-SCALE PELTON TURBINE. MOMENTUM SCIENTIFIC JOURNAL, 15(2). https://doi.org/10.36499/jim.v15i2.3076