Darrieus Water Turbine Performance Configuration of Blade

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Abstract. Horizontal axis Darrieus water turbines, very suitable for use in river flows in the utilization of the kinetic energy. Water turbines studied in this test, is a six-blade Darrieus water turbines. Tests using three configurations of blade arrangements, with conditions rotor sink and drown half. Tests carried out in the watershed Ogan at the village Tabuan Ogan Komering Ulu of South Sumatra Histories. Research results obtained on each configuration of blade, the condition of the rotor and the rotor sink half drowned. High efficiency configuration occurs in parallel arrangement with the condition of the rotor blade sank half.

Keywords: Darrieus Turbines, Configuration of blade, and Rotor Conditions

1. Introduction

The kinetic energy of the water flow of the river is shallow; it is still possible to be use as the needs of the population in village's unreached electrical energy, energy saving and environmental friendly. The beginning of the 19th century already utilizing fluid flow Sathish et. al. [1]. As an example for high head Pelton turbine, medium head turbine Kaplan turbine France head low. In principle, water turbine converts the potential energy of water into mechanical energy in the form of rotation on the shaft, which would then convert into electrical energy through an electric generator.

The working principle of water turbines are group into two, namely the impulse turbine and reaction turbine. Where to impulse turbine for low head cross-flow turbine is, and reaction turbines for low head turbine propeller ie. In 1925, the first time the concept of vertical axis wind turbine by George Jean Marie Darrieus the blade airfoil, then in 1931 developed into Darrieus type turbine water turbine with blade hydrofoil. Alexander M. Gorlov known as Gorlov turbine types develops this type of turbine cross-flow fluid flow in the year 1993-1995; both are very suitable for use in the watershed. Darrieus-type turbine easy to make because it's a straight blade comparison Gorlov turbine blade type. Khan et al. [2] Presenting curves in the selection of several types of conventional turbines. Mohammed et al. [3] Learning the experimental design of helical-type floating water turbine blade.

Darrieus water turbine blade profile and Gorlov Hydrofoil shape, cross-sectional geometry of fluid flow characteristics in the hope of getting a big lift force and drag force is small. Hydrofoil based national advisory Committee for Aeronautics (NACA). Hau et. al. [4] In testing has considered the effects of curvature and thickness distribution were tested with various numbers Renold, the NACA standard numeric code. Matsushita, et. al. [5] in experimentally that the unsteady around the Darrieus turbine blades are asymmetrical stall the flow around the blade. Other, et. al. [6] using Commersial Solver (fluent) to determine the performance of Darrieus water turbines. The results showed that the maximum power coefficient is 0.33 at a tip speed ratio of 1.6 and 0.89 solidity. Kirke, et. al. [7] Darrieus turbine there are drawbacks, namely low starting torque and blade vibrates, to overcome an adjustable blade angle position starting torquen high yield, and also has a high efficiency, while shaking force is still within tolerable limits.

Hantoro et. al. [8] The direction of flow of water coming from the front of the rotor to straight hit blade, so that the rotation speed of the rotor will match the speed of the water flow, so that the tip speed ratio, ratio of blade speed with high water velocity, the propeller will cut off the flow of water with a small angle of attack. Resultant lift force will help rotate the propeller. Stabins et. al. [9] have studied experimentally to reduce the counter-force effects on the Darrieus turbine blades occurs when moving against the flow, so it does not produce torque but still occur due to friction drag. Then the Darrieus turbine turbines mounted horizontally, and most blades are experiencing counter-force effect appears on the surface of the water, so there are some turbine rotor lifted. Thus the torque and turbine efficiency rise. Mc.Adam[10] studied experimentally and variants Darrieus Darrieus (transverse) horizontal axis is almost no difference in power Darrieus Darrieus transverse parallel with only a slight shift of tip speed ratio is larger.

From the description of previous researchers, the authors tried to design water turbin horizontal axis

Darrieus blade, the blade parallel arrangement and configuration of transverse blade. Configuring the blade parallel arrangement the blade portion is in the air to increase efficiency, reduce counter-force effects and drag, rotor lifted partially investigated by Stabins. Variant Darrieus blade (blade arrangement tranverse) horizontal axis, had also been studied experimentally by Mc.Adam. Author of two researchers combining some variables that have not been studied experimentally by the two researchers.

2. Plans and Procedures Research

In this study, the authors designed a horizontal axis Darrieus water turbine diameter d = 500 mm. blade length l = 875 mm. Using a water turbine six blade Darrieus NACA 0020. Darrieus blade solidity σ = 0.25 is chosen, then the chord length is:

$$\sigma = \frac{cB}{\pi d}$$

$$c = \frac{\sigma \pi d}{B} = \frac{0{,}25\,\pi\,500}{6} = 125{,}6\,mm$$

$$c = 65{,}45\,mm$$

Thus, the thickness of the blade Darrieus because using the NACA 0020 profile is:

The thickness of the blade = 20%. 65.45 = 13 mm.

Darrieus water turbine blades made of wood types merawan, and plastic insulated so that the surface becomes slippery and the blade does not absorb water.

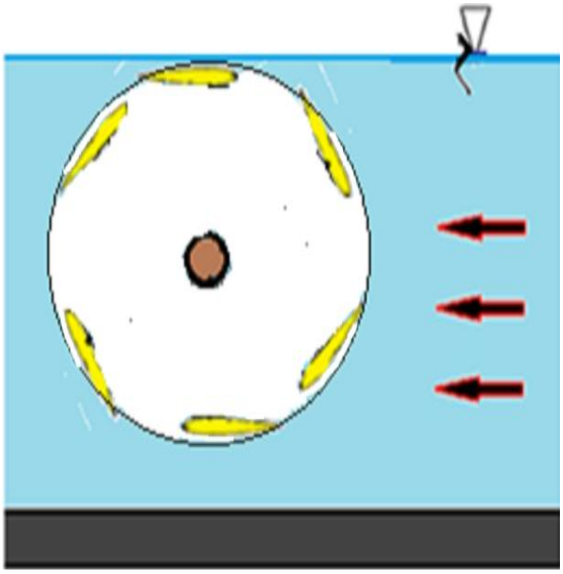

Figure 1. Schematic study (side view)

From Figure 1, the schematic study drowned condition configuration of blade A (parallel blade arrangement), is one of the variables of the study.

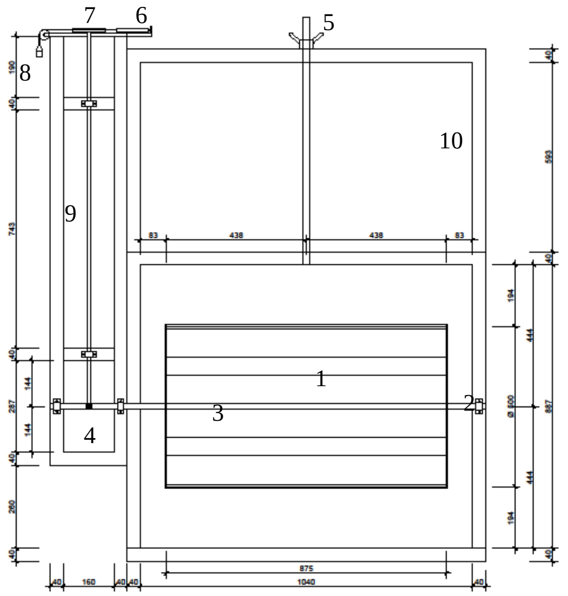

Figure 2. Construction of water turbines

Figure 2 Darrieus water turbine construction to testing, turbine frame is made of iron with a square profile, who completed with wooden blade Darrieus merawan, captions as follows: (1) turbine blades, (2) bearing, (3) the turbine shaft, (4) oblique gear, (5) lift shaft turbine rotor, (6) spring balance, (7) brake drum (pulley), (8) load, (9) vertical axis, and (10) fixed order.

Figure 3. Water Turbine for testing

Water turbine testing, conducted in the Ogan river at the village Tabuan Ogan Komering Ulu Histories of South Sumatera Province. Ogan riverbed in the form of coral, which can be taken by locals for sale. The river was also only used for shower and wash, not for transportation or irrigating rice fields. River depths between 0.5 to 1.5 meters, width of the river about 150 meters. Water flow velocity 0.4 to 1.1 m/s. Testing chosen surface where a constant flow (uniform flow) and not bumpy. Water flow rate in the test 0.6 m/s. It is measured at the time of each test in some areas with current meter rotor area.

In testing the condition of the rotor and the rotor sink half drowned, also changed the composition of the three configurations on the disc rotor blade. The configuration can be seen in the image below:

Figure 4. Configuration of blade A (parallel blades)

Figure 5. Configuration of blade B (transverse blades)

Figure 6. Configuration of blade C (cross blades)

Data processing formula:

$$U_{rotor} = \frac{\pi \text{ d n}}{60} \text{ (m/s)} \quad (1)$$

$$\omega = \frac{2 \pi \text{ n}}{60} \quad (2)$$

After calculating the circumference of the rotor speed U and angular velocity ω, we calculate the tip speed ratio λ by comparing the speed of the rotor, waterpower P_{water}.

$$\lambda = \frac{U_{rotor}}{V_{water}} \quad (3)$$

$$P_{water} = \frac{1}{2} \rho A (V_{water})^3 \quad (4)$$

To get the torque coefficient C_T, we also count on the turbine torque T of the different force on the spring balance and style load. In the calculation of the power turbine, efficiency of gear is also taken into account from the gear shaft horizontal to vertical shaft with a gear ratio of the value of the rotation, meaning that the rotation axis of the horizontal and vertical axis of the same, and finally we calculate the efficiency of the turbine.

$$T = (F_{spring} - F_{load}) \text{ g } r_{pulley} \quad (5)$$

$$C_T = \frac{T}{\frac{1}{2}\rho V^2 A r} \quad (6)$$

$$P_t = \frac{T \ \omega}{\eta_{rg}} \quad (7)$$

$$\eta_t = \frac{P_t}{P_{water}} \ 100 \ \% \quad (8)$$

3. Results and Discussion

This experiment aims to measure the torque coefficient C_T, and power turbine efficiency η_t to the effects of the use conditions Darrieus rotor blade configuration drowning, also experimental conditions of the rotor configuration of blade sinking half. Currentmeter obtained from measurements with a flow rate of water every point of the rotor area V_{water} = 0.6 m/s. Time testing sunny weather, a constant flow velocity in the river during testing, visually almost no height difference during testing and begin testing each recurrent always measured water flow rate was no change in the water flow velocity, mean water flow is uniform. Atmosphere testing can be seen in **Error! Reference source not found.** for the testing of water turbines.

The test results can be presented in the form of C_T images relationship λ, and the relationship η_t – λ.

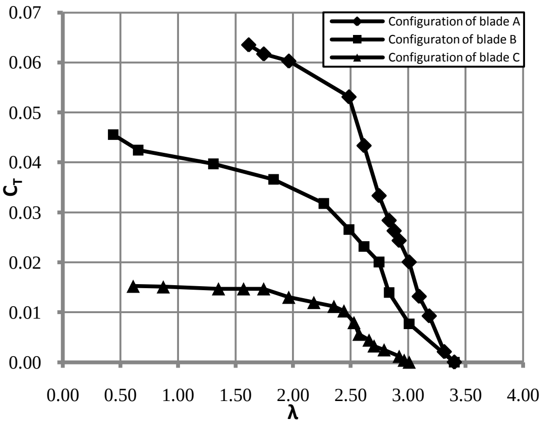

Figure 7. Relationship C_T – λ rotor sink

Figure 7 Relationship C_T – λ sinking of rotor condition, configuration of blade A $C_{T\ max}$ = 0.064 at λ = 1.61, configuration of blade B $C_{T\ max}$ = 0.046 at λ = 0.44, and configuration of blade C $C_{T\ max}$ = 0.015 at λ = 0.61. Torque coefficient happens configuration of blade A large enough value, and occurs in the tip speed ratio is large, meaning that the speed of rotation of the rotor is still high water velocity. Compared configuration of blade B value max C_T values are not too much different, but it happens at $\lambda = 0.44$, meaning that a turbine wheel is quite low, as is the configuration of blade C lower than other blade configurations.

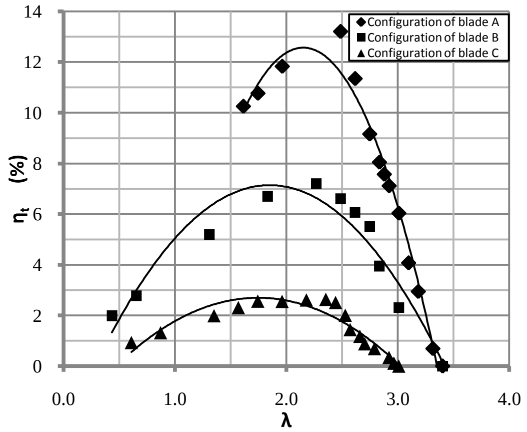

Figure 8. Relationship $\eta_t - \lambda$ rotor sink

Figure 8 Relationship η_t – λ sinking of rotor condition, configuration of blade A, $\eta_{t\ max}$ = 13.01 % at λ = 2.2, configuration of blade B $\eta_{t\ max}$ = 7.02 % at λ = 1.87, and configuration of blade C $\eta_{t\ max}$ = 2.64 % at λ = 1.83. Efficiency turbine blade configuration that occurs A value is 13.01%, meaning more efficient than two other arrangement configuration of blade, efficiency configuration of blade B value is 7.02 %, and the efficiency configuration of blade value is significantly lower C only 2.64 %. At the tip speed ratio is not too much different. Seen from Figure 8, the operational range of configuration of blade B is wider than the other blade configurations.

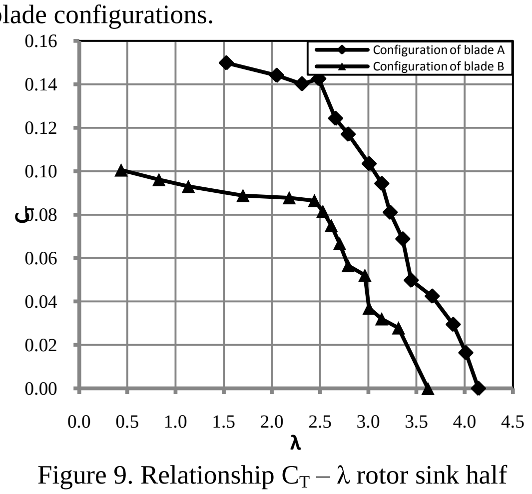

Figure 9. Relationship $C_T - \lambda$ rotor sink half

Figure 9 Relationship C_T – λ sink half rotor condition, configuration of blade A, $C_{T\ max}$ = 0.150 at λ = 1.53, configuration of blade B $C_{T\ max}$ = 0.101 at λ = 0.44. Torque coefficient happens configuration of blade A large enough value and occurs at a tip speed ratio is large, meaning that occur in sufficiently high rounds. Compared to the value of configuration of blade B value is relatively low $C_{T\ max}$ = 0.101, lower tip speed ratio means the turbine wheel is quite low.

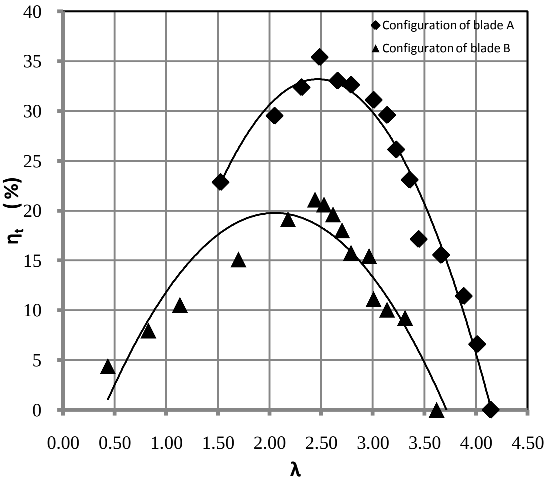

Figure 10. Relationship $\eta_t - \lambda$ rotor sink half

Figure 10 Relationship η_t – λ sink half rotor condition, configuration of blade A, $\eta_{t\ max}$ = 33.01 % at λ = 2.25, configuration of blade B ηt_{max} = 20.01 % at λ = 2.12. Efficiency turbine blade configuration that occurs A value is 33.01 %, meaning more efficient than configuration of blade B, efficiency configuration of blade B value 20.01 %. At the tip speed ratio is not too much different. However, the operational range B is wider blade configuration.

The first test is using six-turbine blade Darrieus, a configuration of blade A (parallel blade arrangement) sinking of rotor condition. From the curve max torque coefficient C_T = 0.064, turbines operational restrictions in the range $1.61 < \lambda < 3.40$, the maximum efficiency $\eta_{t\ max}$ = 13.01% at λ = 2.2. Once the rotor is increased until the condition is conditioned rotor half drowned $C_{T\ max}$ = 0.150, operational limits in the range $1.53 < \lambda < 4.14$, the maximum efficiency $\eta_{t\ max}$ = 33.01 % at λ = 2.25. The range of operational conditions of the rotor sank half as wide.

Both turbines testing using six Darrrieus blade, configuration of blade B (arrangement of transverse blade) rotor sink conditions. From the curve max torque coefficient C_T = 0.046, turbines operational restrictions in the range $0.44 < \lambda < 3.40$, the maximum efficiency $\eta_{t\ max}$ = 7.02 % at λ = 1.87. Once the rotor is increased until the condition is conditioned rotor half drowned $C_{T\ max}$ = 0.101, operational limits in the range $0.44 < \lambda < 3.62$, the maximum efficiency $\eta_{t\ max}$ = 20.01 % at λ = 2.12. The range of operational conditions of the rotor sank half as wide.

Third turbine tested using six Darrieus blade, configuration of blade C (cross blades arrangement) sinking of rotor condition. From the curve max torque coefficient C_T = 0.015, turbines operational restrictions in the range $0.61 < \lambda < 3.01$ maximum efficiency just $\eta_{t\ max}$ = 2.64 % at λ = 1.83.

4. Conclusion

From the experiments that have been performed can be concluded:

1. On the condition of the rotor torque and efficiency coefficient sink turbine blade configuration parallel arrangement better than the configuration of the transverse blade arrangement, configuration and arrangement of blades crossed.
2. The condition of the rotor blade sank half, configuration parallel arrangement better than the configuration of the transverse blade arrangement.

So the best in this test, is the configuration of the parallel arrangement of the condition of the rotor blade sank half-high torque coefficient, i.e. $C_{T\ max}$ = 0.150 and turbine efficiency η_t can reach max = 33.01 %. Drag force of the blade against the flow does not occur, because most of the blade is in the air.

Glossary of Terms and Abbreviations:

A	=	area of the rotor wash of water flow (m2)
B	=	number of blades (fruit)
c	=	width blade chord (m)
C_T	=	coefficient of torque
d	=	diameter rotor (m)
F	=	force (kgf)
g	=	gravity (m/s^2)
l	=	length of blade (m)
P_{water}	=	power of water (W)
P_t	=	power turbine (W)
r_{pulley}	=	the radius of the pulley (m)
T	=	torque (Nm)
U_{rotor}	=	turbine rotor peripheral velocity (m/s)
V_{water}	=	water velocity (m/s)
η_{rg}	=	efficiency of gear (%)
η_t	=	turbine efficiency (%)
λ	=	tip speed ratio
ρ	=	period types of water (kg/m^3)
σ	=	solidity
ω	=	rotor angular velocity (rad/s)

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