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SCOOPLY BLADE FOR LOW CURRENT RIVER WATERWHEEL SUPPORTING THE ENERGY NEEDS IN THE RURAL AREAS OF INDONESIA

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Abstract

A series of experiment has been carried out to measure the effectiveness of the new rotor blades of waterwheel in order to absorb as much as possible the energy of flow water. The scoopy blade is predicted convert more effectively and efficiently the water energy into useful mechanical energy compared to flat blade. This blade is intended to used for undershot waterwheels operated in low current rivers in Indonesia. The scoop blades are tested at a flow range from 0.8 m / sec - 2.5 m / sec in the range of gamma angle 10⁰, 15⁰ and 20⁰. All results are compared to the flat blade where gamma angle is zero. The test results show the scoopy blade with gamma angle 10⁰ is effectively harnessed the water energy compared to others. The blades with gamma angle 10⁰ produce bigger power and bigger efficiency than blades of other gamma angles.

1. Introduction

The previous study [1] shows that the flow velocity of most rivers in South Sumatra is commonly below 1 m / sec. At speeds below 1 m / sec, water are not economical to be used as power generation of water turbine [2]. In case of installation, the current directors are needed to focus and increase the velocity of flow in order to maximize the utilization of its kinetic energy became mechanical power. An other interesting effort to maximize the utility of water energy is developing the blade of turbine itself. In this paper we will discuss the tests results of scoopy blade with varying gamma angle at the tip ranging from 10⁰ to 20⁰ compared to flat blade where the gamma angle is zero.

As stated previously that the author has conducted research on tidal energy in the secondary channel, Telang, Banyuasin South Sumatra.[1] The flat blades applied on the occasion were intended to utilize the alternating water movement of high tide and low tide. From the previous research, we can withdraw conclusions as follows:

1. A lot of energy is lost in the form of flow to all sides of the blade as seen in Fig.1 (a)
2. High corrosion rate to blade metal material regarding the low pH of seawater.
3. Problems with the step-up gear transmission system. [3]



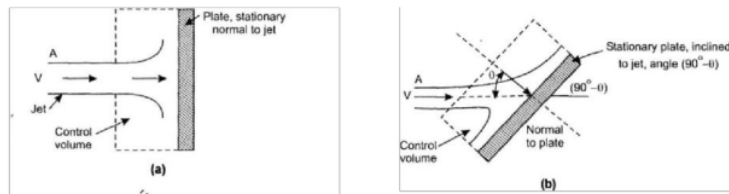


Figure 1. Water flow striking the flat blade [4],[7]

a. Vertical blade position b. Inclined blade position.

This paper represented the test results of the new blade design called Scoopy Blade to maximize the absorption of kinetic energy of water flow by modifying the Pelton turbine blade to be applied to the undershot waterwheel operated in rivers with weak currents. Pelton turbine blades are considered as main inspiration of this scoopy blades for impulse system, that's why we call this new scoopy blade as a modified Pelton Blade. Pelton blades itself cannot be applied to the 'undershot' waterwheel because the Pelton blade is specifically designed for high flow velocity, which are around 100 m / s or greater. While the speed of river water flow ranges from 0.8 m/sec to 2.5 m/s as tested in this experiments. Meanwhile, the previous test results of scoopy blades with gamma angle ranging from 30^0 to 45^0 already published at the passed semester [7] showing that the bigger gamma angle of the blade the bigger energy absorbed but the efficiency decreases by increasing gamma angle. These results encourages us to continue the testing at smaller gamma angle. The test results show the effectiveness of the blade at gamma angle 10 degrees which is indicated by the power generated and the efficiency obtained. .

By the effective blade, the effective energy will extracted from the water. Indonesia with many large and small rivers have big potential energy from the water. International Hydropower Association (IHA) reported that Indonesia technical hydropower potential is estimated at around 75,000 MW, with untapped concentrated on Java, Sulawesi and Sumatra islands. It is also estimated that there is currently about 8 GW of economical undeveloped hydropower potential, which would provide nearly 33 TWh electricity power per year [8]. This energy will sufficiently fulfill the areas with off-grid electricity such as rurals and remote islands.

2. View of Theory

Waterwheel works on three basic principles: Uppershot, Breastshot and Undershot. The application is depending on the availability of water sources.[6]

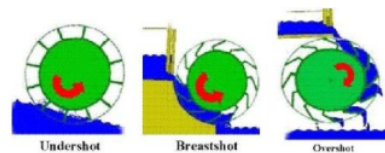


Figure 2. Three working principles of waterwheel [6] [7]

As mention previously, the flat blade enable the water to flow freely to the sides of blades as shown in Figure 1. These flow are energy lost which must be minimized by modifying the blade shape. The scoopy blades are designed to prevent the energy losses, where the sides flow on blades surface are blocked by side walls. By the way, to ensure the blade can operate safely in acid water, the blade

material used in this experiments is made of reinforced PMC (Polymer Matrix Composite) with steel wire mesh to resist corrosion and hold the water collision acting on it.

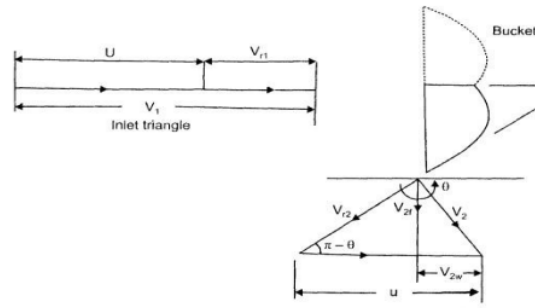


Figure 3. Pelton Blade with a speed triangle at the inlet and outlet.[4] [7]

Where:

U = peripheral speed of the blade (rad / second)

V_{r1} = relative velocity of inlet flow (m /

sec) V_1 = absolute velocity of inlet flow (m / sec)

V_{r2} = the relative velocity of flow out of the blade. V_{2f} = blade outflow speed (m/sec). V_2 = absolute velocity of flow out of blade (m/sec).

There are several types of resins in the market, i.e: Polyaster Oprthopthalic, Polyester Isophthalic, Epoxy, Vinyl Ester, Phenolic and Yukalac. Almost all of these resins are resistant to corrosion and resist to acid solution. With corrosion resistance and acid resistance, this bla will able to operate in low pH environment such as seawater. Blades in this experiments are made of Unsaturated Polyester Type 2668 WNC resins with MEPOXE (Methyl Ethyl Ketone Peroxide) as hardener. The blades are made by pouring the mixed resin into preprepared moldings. The size of scoopy blades are 100 mm x 120 mm.

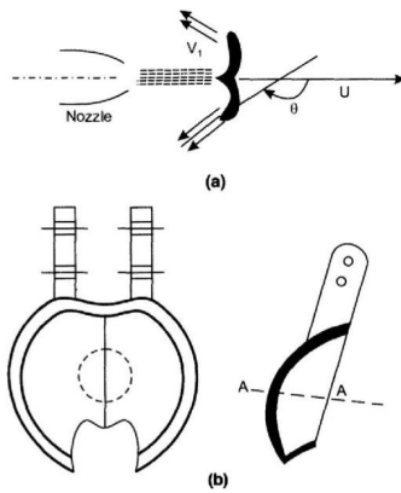


Figure 4. Pelton blade.[4] ;[7]

- a. Pelton blades with jet breakers at the center and incline arc wall on the sides to avoid interference.
- b. Pelton blades with handle holder viewed from the front and side.

3. Modified Pelton Blade

The basic shape and the size of Pelton Blades are shown in Figure 5. Pelton blades are work effectively for high-speed flowing water, but not effective for low speeds such as river flow. Therefore we need a concept that is tested for truth. The concept is based on modified Pelton blade and we call it Scoopy Blade.

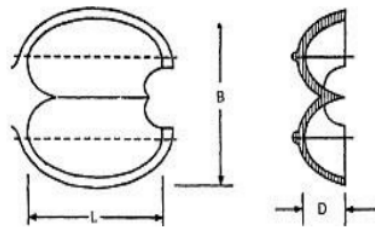


Figure 5. Pelton blades and sizes

Where: $L = 2 - 3 D$; $B = 3-5 D$ dan $D = 0,8 - 1,2$ nozzle diameter[4] [7]

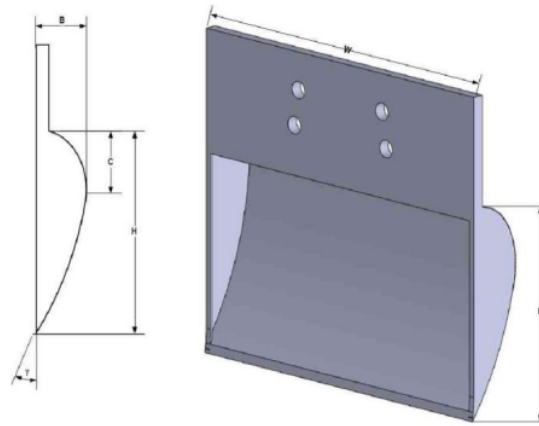


Figure 6. Modified Pelton blades called Scoopy Blade

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Figure 6 shows a modified Pelton blade for low speed water flow $0.8 \text{ m/s} - 2.5 \text{ m/sec}$. [5] This blade is consist of vertical walls on the left and right side, and the inclined curved surface with gamma angle at the tip. The range of gamma angle in this experiment is made of 0° to 20° . The 0° expressing the flat blade and the inclined curved scoopy blade expressed by gamma angle $10^\circ - 20^\circ$. The scoopy blade is intended to accomodate as much kinetic energy as possible and convert it into mechanical work. The blade wall is intended to minimize the sides outflow and maximize the force of water acting on blades.

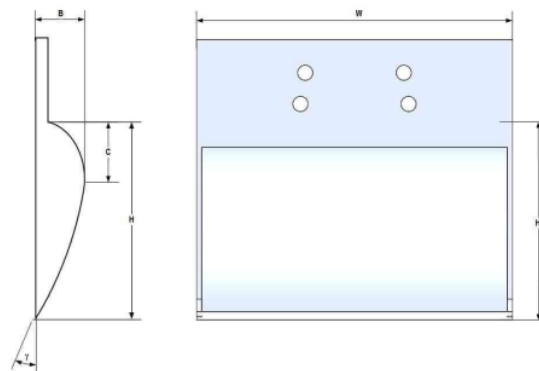


Figure 7. Pelton modification blade for undershot waterwheel with gamma angle at the tip.

Gamma angle at the tip of blade is influence the direction of Vr_2 and the magnitude of $V2f$ accordingly. Consequently, the peripheral velocity of blade will increase and the power of turbine will raised.

4. Method of Measurement and Calculation

The revolution of wheel is measured manually for a unit of time. The torsion on shaft is measured by dynamometric method, where the shaft loaded by certain weight and the force bear by the shaft read on the balance. From the data found, we can calculate the peripheral velocity of the wheel by the following formula:

$$U_{\text{blade}} = (\pi \cdot D \cdot N) / 60 \quad (\text{m/sec})$$

Water power available to turbine obtained by:

$$P_{\text{water}} = 1/2 \cdot \rho \cdot (V_{\text{water}})^3 \quad (\text{Watt})$$

Waterwheel power is:

$$P_t = (T \times \omega) / \eta_t \quad (\text{Watt})$$

Power coefficient:

$$C_p = P_t / P_{\text{water}}$$

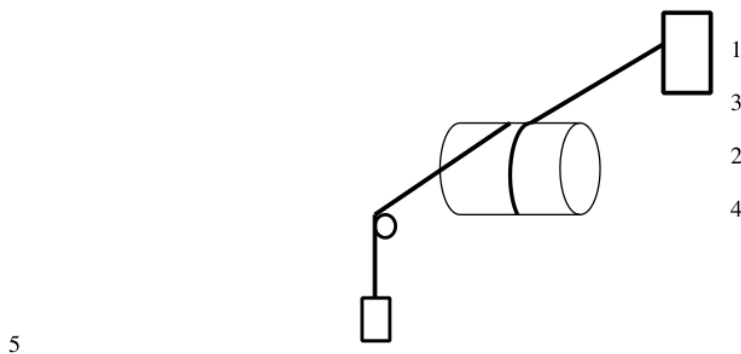


Figure 8. The method of torque measurement at shaft

1. Balance
2. Shaft
3. Rope
4. Roll
5. Load

The first year experiments has already conducted for the range of gamma angle from 30⁰ to 45⁰. The results are already published in the International Journal of Science and Research [7]. The second year experiments is now reported, from the gamma angle 0⁰ to 20⁰. The results are as follows:

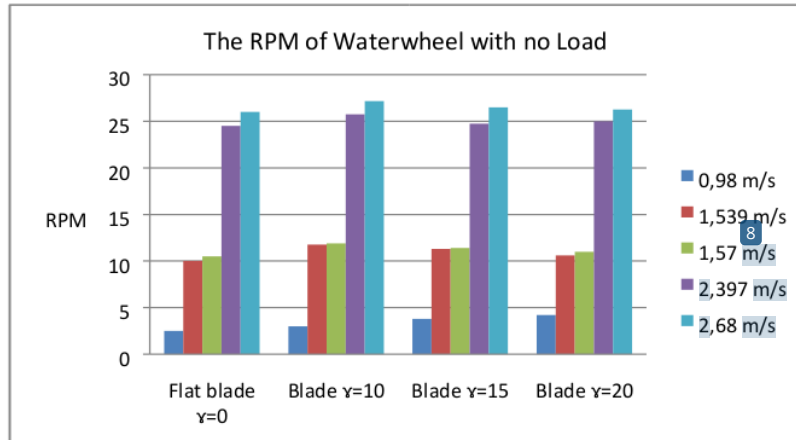


Figure 9. A slight increment of wheel revolution per-minute at varying speed of flow where γ=10⁰ showed the good performance.

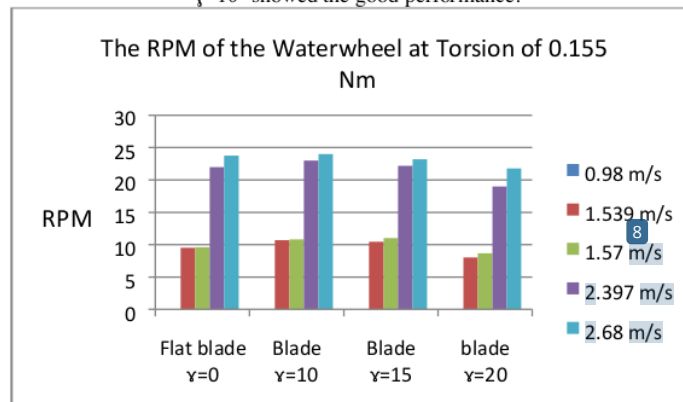


Figure 10. The revolution of the wheel per minute at torsion of 0.155 Nm. The blade with γ =10⁰ showed good performance.

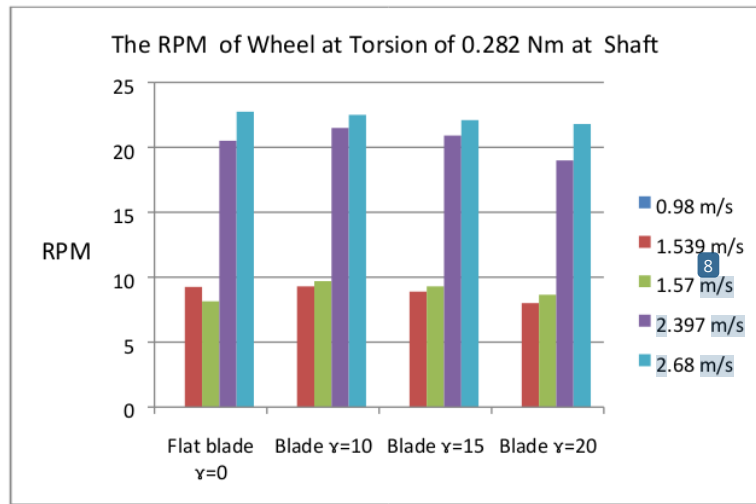


Figure 11. The RPM of the wheel at torsion of 0,282 Nm. The blade with $\gamma = 10^0$ showed better performance compared to other angles.

Figure 10 and Figure 11 show a good performance of blade with gamma angle 10^0 compared to other angle at velocity of flow ranging from 1.539 m/s to 2.397 m/s. This phenomenon indicating that the water current energy is absorbed more effectively at the blade with gamma angle 10^0 .

The effectivity of $\gamma=10^0$ blade clearly reflected by figure 12, where the better output power is shown by blade with gamma angle 10^0 . The blade with gamma angle bigger than 10^0 tend to absorb the water energy too, but the efficiency and the effectiveness tend to decrease.

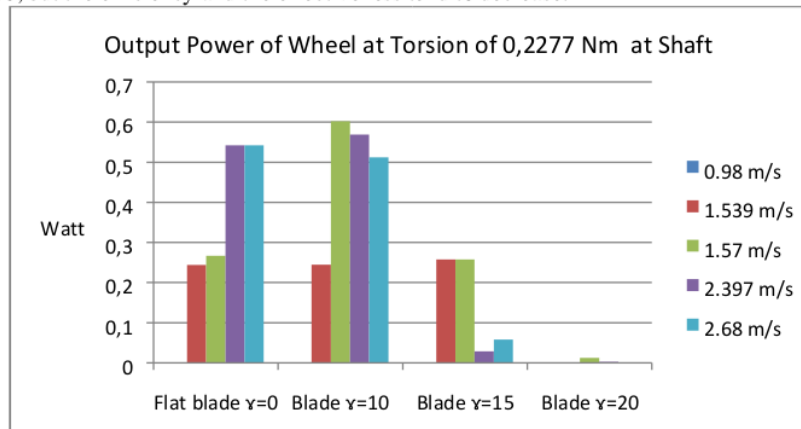


Figure 12. The output power of waterwheel at torsion of 0,2277 Nm. The graph shows the blade with gamma angle 10^0 showing good performance at the velocity between 1.539 m/s - 1.57 m/s

5. Conclusions

From the results represented, analysis and tendency of obtained data conclusions can be withdrawn from the above discussions, as follows:

1. Scooped blade absorbs more energy than flat blade.
2. The blades with a gamma angle of 10° show a better performance compared to other angles, mainly at the speed 1.39 m/s to 1.57 m/s.
3. The bigger the gamma angle of blade, the bigger the power obtained but the lower the efficiency of turbine.

Acknowledgement

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