



A Study Of The Optimal Performance Of A Mini Hydro Turbine Generator Based On Flow Rate Variations

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ABSTRACT

Efforts to generate electrical energy are by utilizing water turbines as generator drivers. Mini water turbine generators are one alternative solution. The performance testing of this mini water turbine prototype uses water flow from a reservoir which is forwarded through a pump based on variations in discharge using a 220 Volt AC dimmer. The mini water turbine prototype is a crossflow turbine (Banki) type water turbine, has 21 blades, an inlet (nozzle) diameter of 2.5 mm, an outlet diameter of 15 mm and an axial gap of 0.2 - 1.0 mm. In this test, a 12 Volt DC LED lamp load was used. The results of this water turbine prototype test produced the highest efficiency of 54.6% at a water flow rate of 5.7 (liters/minute), a DC electric current of up to 423 (Ma) with a power of 4.03 Watts and a voltage of 9.53 Volts.

Keywords: Electrical Energy, Mini water turbines, Efficiency

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1. Introduction

The continuous growth of the population has led to an increase in electricity consumption, resulting in a growing demand for electrical energy. To anticipate potential energy shortages in Indonesia, the utilization of new and renewable energy (NRE) sources should be encouraged, given the country's abundant renewable energy potential. This is particularly important because fossil fuel reserves, including coal, natural gas, and petroleum, are gradually depleting. Furthermore, fossil fuels are non-renewable resources that can cause environmental damage.

One alternative approach to addressing potential energy shortages is to convert the potential and kinetic energy of water into electrical energy using water turbines. According to the Directorate General of Water Resources, as of April 1, 2022, Indonesia's water resource potential was estimated at 2.78 trillion m³ per year, of which approximately 691.31 billion m³ per year was potentially available for utilization. Meanwhile, according to the Class II Climatology Station of the Meteorology,

Climatology, and Geophysics Agency (BMKG) in East Java, the estimated rainfall in Malang during July, August, and September 2023 was approximately 0–20 mm.

Currently, many mini hydro turbine-generator units are commercially available through online marketplaces. However, the products offered are generally not accompanied by experimental performance test data. Therefore, investigating the performance of these commercially available mini hydro turbine-generator units is important to determine their actual performance characteristics and assess their potential for practical application.

Mini hydro turbine-generators are designed to produce relatively small amounts of electrical energy. In this study, a mini hydro turbine prototype was developed using water supplied from a storage tank through a pump. The water flow rate was varied using an AC dimmer operating at 220 V. The flowing water then struck the guide vanes attached to the rotor, causing the rotor to rotate. The rotational motion was subsequently

transmitted to a generator, which converted mechanical energy into electrical energy. Perhitungan untuk mengetahui besarnya energi yang diperoleh dari air bergantung kepada (ρ) = massa jenis air (kg/m^3), (Q) = debit air (m^3/s), (g) = gravitasi = (m/s^2), (h) = ketinggian efektif (m).

2. Methodology of Research

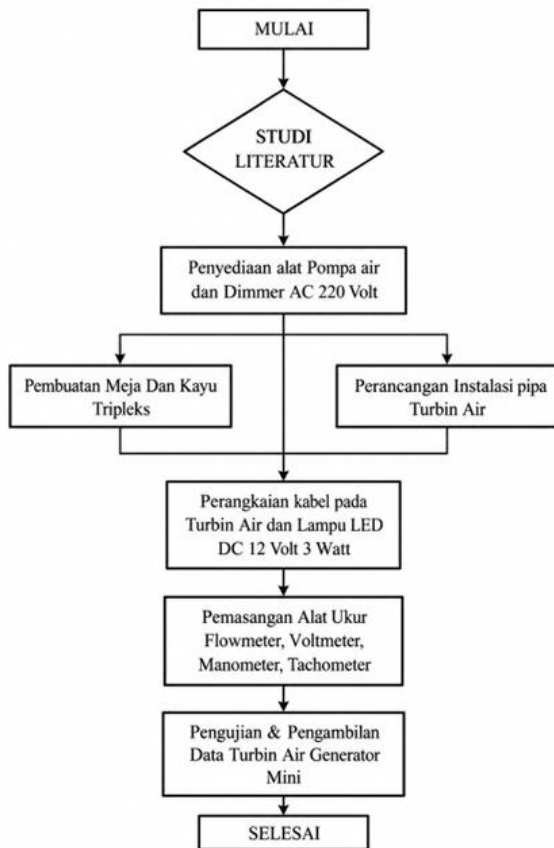


Figure 1. Research Flowchart

This study aims to determine the highest efficiency achieved by a mini hydro turbine-generator using an experimental research method. The experiments were conducted at the Machine Performance Testing Laboratory, Department of Mechanical Engineering, Faculty of Engineering, Universitas Merdeka Malang. During the experiments, data were collected from tests of the mini hydro turbine-generator under variations in water flow rate. The measured parameters were as follows:

1. Electrical voltage (V)
2. Electrical current (A)
3. Turbine rotational speed (rpm)

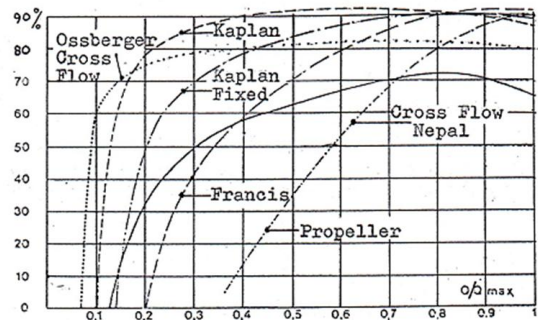


Figure 2. Efficiency Curves of Several Turbine Types with Flow Rate Reduction as the Independent Variable

a. Dependent Parameters

- Potential pressure
- Water flow rate
- Turbine rotational speed
- Electrical voltage
- Electrical current

b. Independent Parameter

- Water flow rate variation

c. Research Equipment

1. Table and Plywood Board

- Table frame material: Hollow steel, $30 \times 30 \times 1.2 \text{ mm}$
Length: 1,660 mm
Width: 510 mm
- Plywood board dimensions:
Length: 1,795 mm
Width: 110 mm
Thickness: 10 mm
- Distance between the water tank and the pump: 1,430 mm



Figure 3. Table and Plywood Board

2. Water Pump

- Model: Fuyou FY-125
- Capacity: 32 L/min
- Suction lift: 9 m

- Discharge head: 15 m
- Total head: 24 m
- Power output: 125 W
- Rotational speed: 2,850 rpm



Figure 4. Water Pump

3. AC Dimmer
 - Input voltage: AC 110–220 V
 - Maximum power: 2,000 W
 - Output voltage: AC 90–220 V



Figure 5. AC Dimmer

4. 12 V LED Lamp



Figure 6. 12 V LED Lamp

5. Water Storage Tank



Figure 7. Water Storage Tank

6. Electrical Cables



Figure 8 Electrical Cables 1 (+ -)

7. Manometer 2,5 kg/cm³



Figure 9 Manometer 2,5 kg/cm³

8. digital flowmeter



Figure 10 digital flowmeter

9. Avometer



Figure 11 Avometer

10. Voltmeter 1 Ampere



Figure 12 Voltmeter

11. Tachometer



Figure 13 Tachometer

3. Result and Discussion

3.1 Experimental Data

The parameters used in the experimental analysis were as follows:

- Water density ((ρ)): 998 kg/m³
- Mechanical efficiency ((η_m)): 70% (obtained from Figure 2.10)
- Gravitational acceleration ((g)): 9.81 m/s²

Table 1. Experimental Results

N o	Tekanan H (kg/cm ²)	Debit Q (L/min)	Putaran n (rpm)	Tegangan V (V)	Arus I (mA)	Generator EHP (W)	Turbin WHP (W)	Efisiensi (%)	Kecepatan Angular	Torsi (Nm)
1	0.14	3.04	827	7.32	2.5	0.0183	0.6945	2.6	86.60324	0.0056
2	0.15	3.15	869.9	7.46	2.9	0.0216	0.7710	2.8	91.09571	0.0059
3	0.16	3.20	904.3	7.49	5.0	0.0375	0.8354	4.5	94.69807	0.0062
4	0.17	3.25	906.8	7.52	10.5	0.0790	0.9015	8.8	94.95987	0.0066
5	0.18	3.30	929	7.54	34	0.2564	0.9692	26.4	97.28465	0.0070
6	0.18	3.68	940.3	7.62	37.6	0.2865	1.0809	26.5	98.46759	0.0077
7	0.20	3.73	994.9	7.77	43	0.3341	1.2173	27.4	104.1857	0.0082
8	0.21	4.16	1016	7.79	50	0.3895	1.4255	27.3	106.3953	0.0094
9	0.23	4.34	1105	8.02	60.3	0.4836	1.6288	29.7	115.7153	0.0099
10	0.25	4.59	1124	8.03	75	0.6023	1.8724	32.2	117.7050	0.0111
11	0.28	4.90	1167	8.19	89.1	0.7297	2.2387	32.6	122.2080	0.0128
12	0.29	5.20	1222	8.34	115.1	0.9599	2.4606	39.0	127.9675	0.0135
13	0.30	5.43	1311	8.44	139.3	1.1757	2.6581	44.2	137.2816	0.0136
14	0.31	5.50	1337	8.48	161	1.3653	2.7821	49.1	140.0103	0.0139
15	0.32	5.57	1390	8.65	170.7	1.4766	2.9084	50.8	145.5605	0.0140
16	0.33	5.70	1437	8.70	192.7	1.6765	3.0693	54.6	150.4823	0.0143
17	0.34	5.90	1455	8.72	203	1.7702	3.2733	54.1	152.3672	0.0150
18	0.35	6.00	1487	8.74	213	1.8300	3.4266	53.4	155.7183	0.0154
19	0.36	6.20	1498	8.76	221	1.9360	3.6420	53.8	156.8702	0.0163
20	0.37	6.40	1507	8.77	229	2.0083	3.8639	52.0	157.8127	0.0171
21	0.40	6.59	1528	8.81	242	2.1320	4.3012	49.6	160.0118	0.0188
22	0.41	6.70	1581	8.88	263	2.3354	4.4824	52.1	166.1903	0.0189
23	0.43	6.72	1619	8.98	286	2.5683	4.7150	54.5	169.5413	0.0195
24	0.46	6.90	1629	9.00	297	2.6730	5.1791	51.6	170.5885	0.0213
25	0.48	7.31	1720	9.12	320	2.9184	5.7254	51.0	180.1180	0.0223
26	0.49	7.40	1730	9.17	333	3.0536	5.9167	51.6	181.1652	0.0229
27	0.49	7.44	1767	9.22	342	3.1532	5.9486	53.0	185.0398	0.0225
28	0.50	7.48	1785	9.23	348	3.2120	6.1027	52.6	186.9248	0.0229
29	0.50	7.50	1799	9.25	352	3.2560	6.1130	53.2	188.3908	0.0227
30	0.51	7.60	1838	9.32	368	3.4298	6.3246	54.2	192.4749	0.0230
31	0.52	7.70	1856	9.35	377	3.5250	6.5334	54.0	194.3599	0.0235
32	0.53	7.82	1864	9.38	384	3.6019	6.7629	53.3	195.1976	0.0243
33	0.54	7.87	1880	9.40	390	3.6660	6.9345	52.9	196.8731	0.0247
34	0.55	7.90	1901	9.42	394	3.7115	7.0899	52.3	199.0723	0.0249
35	0.55	8.00	1922	9.44	401	3.7854	7.1796	52.7	201.2714	0.0250
36	0.56	8.07	1926	9.45	404	3.8178	7.3741	51.8	201.6902	0.0256
37	0.56	8.11	1932	9.46	405	3.8313	7.4107	51.7	203.3658	0.0255
38	0.57	8.17	1945	9.49	412	3.9093	7.5988	51.5	203.6799	0.0261
39	0.57	8.24	1946	9.51	417	3.9657	7.6639	51.7	203.7846	0.0263
40	0.58	8.27	1952	9.52	420	3.9984	7.8268	51.1	204.4130	0.0268
41	0.58	8.28	1953	9.53	423	4.0312	7.8362	51.4	204.5177	0.0268

In this experiment, tests were conducted at different water flow rates ranging from 3.04 to 8.28 L/min.

Q : water flow rate (m³/detik)

H : effective hydraulic head (kg/cm²)

3.2. Calculation Results

3.2.1 Water Turbine Power (Water Horsepower, WHP)

The hydraulic power available to the turbine can be determined from the water flow rate ((Q)) and the effective head ((H)). The theoretical hydraulic power is calculated using the following equation:

$$P = p \cdot g \cdot Q \cdot H$$

where :

P : power (watt)

p : water density (kg/m³) = Pair = 998 kg/m³

g : gravitational (m/detik²) = 9,81 m/detik²

$$P = p \cdot g \cdot Q \cdot H$$

$$P = 998 \text{ kg/cm}^3 \cdot 9,81 \text{ m/detik}^2 \cdot 3,04 \text{ m}^3/\text{detik} \cdot 0,14 \text{ kg/cm}^2$$

$$P = 4166,785 \cdot 10 / 60000$$

$$P = 0,6945 \text{ Watt}$$

- Electric Horse Power (EHP)

$$EHP = V \cdot I$$

EHP : power (watt)

V : Voltase

I : Ampere

$$EHP = V \cdot I$$

$$EHP = 7,32 \text{ volt} \cdot 2,5 \text{ Ampere} / 1000$$

$$EHP = 0,0183 \text{ Watt}$$

- Efisiensi (%)

$$\eta = EHP/WHP$$

$$\eta = EHP/WHP$$

$$\eta = (0,0183 \text{ Watt}) / (0,69446 \text{ Watt}) \times 100$$

$$\eta = 2,6 \%$$

- Angular Velocity

$$\omega = 2 \pi / 60 \cdot n$$

where :

ω : angular velocity (rps)

n : turbine rotational speed (rpm)

$$\omega = 2 \pi / 60 \cdot n$$

$$\omega = 2 \pi / 60 \cdot 827 \text{ (rpm)}$$

$$\omega = 86,60 \text{ rps}$$

- Torque (Nm)

$$T = \eta \cdot WHP / \omega$$

where :

T : Torque (Nm)

η : Mechanical efficiency of the turbine = 70% (obtained from Figure 2.2)

WHP : Watt Horse Power

ω : angular velocity (rps)

$$T = \eta \cdot WHP / \omega$$

$$T = 70\% \cdot 0,69446 \text{ Watt} / 86,603 \text{ rps}$$

$$T = 0,0056 \text{ Nm}$$

3.2.2. Analysis of the Relationship between WHP and EHP (W) and Water Flow Rate (L/min)

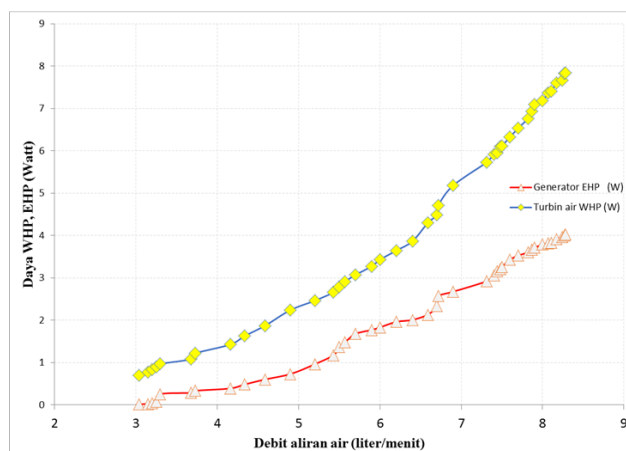


Figure 14. Relationship between WHP and EHP (W) and Water Flow Rate (L/min)

Based on Figure 15, both water horsepower (WHP) and electrical horsepower (EHP) increase as the water flow rate increases. This occurs because the available hydraulic power is influenced by the water flow rate, which drives the turbine blades. The rotational motion of

the turbine is then transmitted through the rotor connected to the generator, enabling the conversion of mechanical energy into electrical energy.

At a water flow rate of 8.28 L/min, the electrical power output of the generator (EHP) reaches 4 W, while the hydraulic power available to the water turbine (WHP) reaches 7.83 W. These results indicate that increasing the water flow rate can improve the power output of the mini hydro turbine-generator system under the tested operating conditions.

3.2.3 Analysis of the Relationship between Rotational Speed (rpm) and Water Flow Rate (L/min)

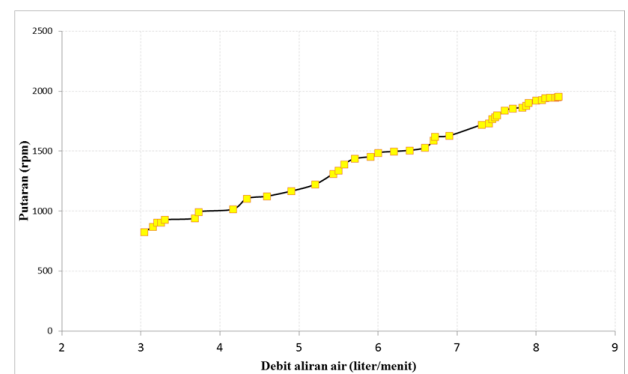


Figure 15. Relationship between Rotational Speed (rpm) and Water Flow Rate (L/min)

Based on Figure 16, the turbine rotational speed increases as the water flow rate increases. This trend occurs because the flowing water imparts momentum to the turbine blades, causing the rotor to rotate. The rotational motion is then transmitted to the generator connected to the rotor, enabling the conversion of mechanical energy into electrical energy. The highest turbine rotational speed recorded in this experiment was 1,953 rpm at a water flow rate of 8.28 L/min.

3.2.4 Analysis of the Relationship between Efficiency (%) and Water Flow Rate (L/min)

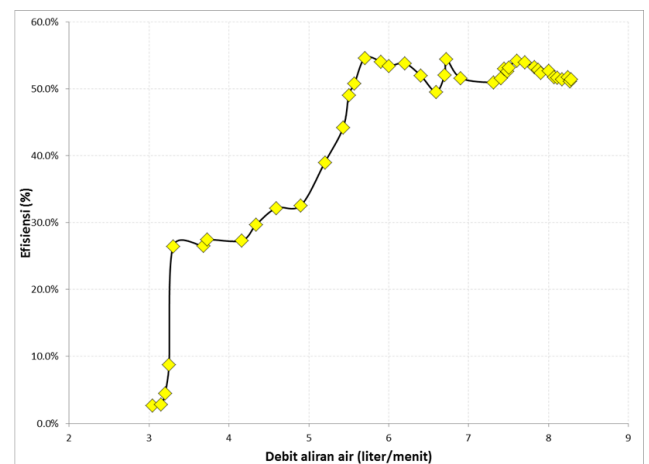


Figure 16. Relationship between Efficiency (%) and Water Flow Rate (L/min)

Based on Figure 17, the efficiency of the mini hydro turbine-generator generally increases with increasing water flow rate within the tested operating range. This trend is associated with changes in the power produced by the turbine and the electrical power output of the generator. However, the highest efficiency does not necessarily occur at the maximum flow rate. In this experiment, the highest recorded efficiency was approximately 54.6% at a water flow rate of 5.7 L/min.

4. Conclusion

Based on the experimental results obtained from the mini hydro turbine-generator, the following conclusions can be drawn:

1. At the lowest tested water flow rate of 3.04 L/min, the mini hydro turbine-generator produced an electrical voltage of 7.32 V, an electrical current of 2.5 mA, a rotational speed of 827 rpm, and a reported power output of 0.6944464 W. At the highest tested water flow rate of 8.28 L/min, the system produced an electrical voltage of 9.53 V, an electrical current of 423 mA, a rotational speed of 1,953 rpm, and a reported power output of 7.83 W.
2. The highest efficiency recorded during the experiment was 54.6%, achieved at a water flow rate of approximately 5.7 L/min. This result indicates that the optimum efficiency occurred at an intermediate flow rate rather than at the maximum tested flow rate.

Referensi

- [1] Z. de Souza and G. L. Tiago Filho, *Pelton and Crossflow Impulse Hydraulic Turbines*. Cham, Switzerland: Springer, 2025, doi: 10.1007/978-3-031-87086-6.
- [2] G. Cornetti, *Hydraulic Machines and Energy*. Cham, Switzerland: Springer, 2024, doi: 10.1007/978-3-030-91601-5.
- [3] G. I. Krivchenko, *Hydraulic Machines: Turbines and Pumps*, 2nd ed. Boca Raton, FL, USA: Lewis Publishers, 1994.
- [4] J. S. Gulliver and R. E. A. Arndt, Eds., *Hydropower Engineering Handbook*. New York, NY, USA: McGraw-Hill, 1991.
- [5] A. R. Inversin, *Micro-Hydropower Sourcebook: A Practical Guide to Design and Implementation in Developing Countries*. Washington, DC, USA: NRECA International Foundation, 1986.
- [6] S. L. Dixon and C. A. Hall, *Fluid Mechanics and Thermodynamics of Turbomachinery*, 6th ed. Oxford, U.K.: Butterworth-Heinemann, 2010.
- [7] Y. A. Çengel and J. M. Cimbala, *Fluid Mechanics: Fundamentals and Applications*, 3rd ed. New York, NY, USA: McGraw-Hill, 2014.
- [8] M. Nechleba, *Hydraulic Turbines: Their Design and Equipment*. Prague, Czechoslovakia: Artia, 1957.