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LAMPIRAN

Lampiran A

A. 1. Tabel varias kemiringan sudu turbin

Variasi sudu
18°
23°
28°

5.2.1.1. 2. Tabel diameter lingkaran pipa

Variasi sudut	Diameter lingkaran pipa	Diameter lingkaran pipa
	(inch)	(m)
18°	3	0,0762
23°	3	0,0762
28°	3	0,0762

A. 3. Tabel jari-jari lingkaran pipa

Variasi sudut	jari jari lingkaran pipa
	(m)
18°	0,0381
23°	0,0381
28°	0,0381

A. 4. Tabel jari-jari pully

Variasi sudut	Jari-jari pully (L)
	(m)
18°	0,0085
23°	0,0085
28°	0,0085

A. 5. Tabel putaran (rpm) pada putaran 18°

Variasi sudu	Putaran (rpm)
18°	200
	300
	400
	500
	600

A. 6. Tabel putaran (rpm) pada putaran 23°

Variasi sudu	Putaran (rpm)
23°	200
	300
	400
	500
	600

A. 7. Tabel putaran (rpm) pada putaran 28°

Variasi sudu	Putaran (rpm)
28°	200
	300
	400
	500
	600

A. 8. Tabel beban pada variasi sudu 18°

Variasi sudu	Beban (gram)	Beban (kg)
18°	100	0,1
	200	0,2
	300	0,3
	400	0,4
	500	0,5

A. 9. Tabel beban pada variasi sudu 23°

Variasi sudu	Beban (gram)	Beban (kg)
23°	100	0,1
	200	0,2
	300	0,3
	400	0,4
	500	0,5

A. 10. Tabel beban pada variasi sudu 28°

Variasi sudu	Beban (gram)	Beban (kg)
28°	100	0,1
	200	0,2
	300	0,3
	400	0,4
	500	0,5

A. 11. Tabel waktu untuk tiap variasi putaran (rpm) pada sudut kemiringan sudu

a. Tabel waktu 18°

Variasi sudut kemiringan sudu	Putaran	No	Beban	Waktu
	200	1	100	2,58
		2	200	2,49
		3	300	2,37
		4	400	2,26
		5	500	2,12
	300	1	100	2,21
		2	200	2,14
		3	300	2,06
		4	400	1,94
		5	500	1,79
	400	1	100	1,96
		2	200	1,86
18°		3	300	1,78
		4	400	1,7
		5	500	1,56
	500	1	100	1,77
		2	200	1,65
		3	300	1,56
		4	400	1,46
		5	500	1,34
	600	1	100	1,55
		2	200	1,41
		3	300	1,33
		4	400	1,25
		5	500	1,13

b. Tabel waktu 23°

Variasi sudut kemiringan sudu	Putaran	No	Beban	Waktu
23°	200	1	100	2,32
		2	200	2,22
		3	300	2,14
		4	400	2,06
		5	500	1,94
	300	1	100	1,98
		2	200	1,87
		3	300	1,79
		4	400	1,71
		5	500	1,59
	400	1	100	1,74
		2	200	1,66
		3	300	1,57
		4	400	1,48
		5	500	1,35
	500	1	100	1,54
		2	200	1,47
		3	300	1,39
		4	400	1,29
		5	500	1,17
	600	1	100	1,3
		2	200	1,24
		3	300	1,18
		4	400	1,09
		5	500	0,97

c. Tabel waktu 28°

Variasi sudut kemiringan sudu	Putaran	No	Beban	Waktu
28°	200	1	100	2,09
		2	200	1,98
		3	300	1,91
		4	400	1,82
		5	500	1,71
	300	1	100	1,76
		2	200	1,67
		3	300	1,59
		4	400	1,5
		5	500	1,4
	400	1	100	1,52
		2	200	1,42
		3	300	1,34
		4	400	1,25
		5	500	1,15
	500	1	100	1,31
		2	200	1,23
		3	300	1,16
		4	400	1,08
		5	500	0,98
	600	1	100	1,13
		2	200	1,06
		3	300	0,97
		4	400	0,89
		5	500	0,77

A. 12. Tabel pengamatan sudut kemiringan sudu 18°

Variasi sudut	Putaran (n)	Beban	Debit air (Q)	Kecepatan air (v)	Densitas air (ρ)
	(rpm)	(gram)	(m^3/s)	(m/s)	(kg/m^3)
	200	100	0,0039	0,8504	1000
	200	200	0,0040	0,8811	1000
	200	300	0,0042	0,9257	1000
	200	400	0,0044	0,9708	1000
	200	500	0,0047	1,0349	1000
	300	100	0,0045	0,9927	1000
	300	200	0,0047	1,0252	1000
	300	300	0,0049	1,0650	1000
	300	400	0,0052	1,1309	1000
	300	500	0,0056	1,2257	1000
	400	100	0,0051	1,1193	1000
	400	200	0,0054	1,1795	1000
18°	400	300	0,0056	1,2325	1000
	400	400	0,0059	1,2905	1000
	400	500	0,0064	1,4064	1000
	500	100	0,0056	1,2395	1000
	500	200	0,0061	1,3296	1000
	500	300	0,0064	1,4064	1000
	500	400	0,0068	1,5027	1000
	500	500	0,0075	1,6373	1000
	600	100	0,0065	1,4154	1000
	600	200	0,0071	1,5560	1000
	600	300	0,0075	1,6496	1000
	600	400	0,0080	1,7551	1000
	600	500	0,0088	1,9415	1000

A. 13. Tabel pengamatan sudut kemiringan sudu 23°

Variasi sudut	Putaran (n)	Beban	Debit air (Q)	Kecepatan air (v)	Densitas air (ρ)
	(rpm)	(gram)	(m^3/s)	(m/s)	(kg/m^3)
	200	100	0,0043	0,9457	1000
	200	200	0,0045	0,9883	1000
	200	300	0,0047	1,0252	1000
	200	400	0,0049	1,0650	1000
	200	500	0,0052	1,1309	1000
	300	100	0,0051	1,1080	1000
	300	200	0,0053	1,1732	1000
	300	300	0,0056	1,2257	1000
	300	400	0,0058	1,2830	1000
	300	500	0,0063	1,3798	1000
	400	100	0,0057	1,2609	1000
	400	200	0,0060	1,3216	1000
23°	400	300	0,0064	1,3974	1000
	400	400	0,0068	1,4824	1000
	400	500	0,0074	1,6251	1000
	500	100	0,0065	1,4246	1000
	500	200	0,0068	1,4925	1000
	500	300	0,0072	1,5784	1000
	500	400	0,0078	1,7007	1000
	500	500	0,0085	1,8751	1000
	600	100	0,0077	1,6876	1000
	600	200	0,0081	1,7693	1000
	600	300	0,0085	1,8593	1000
	600	400	0,0092	2,0128	1000
	600	500	0,0103	2,2618	1000

A. 14 Tabel pengamatan sudut kemiringan sudu 28°

Variasi sudut	Putaran (n)	Beban	Debit air (Q)	Kecepatan air (v)	Densitas air (ρ)
	(rpm)	(gram)	(m^3/s)	(m/s)	(kg/m^3)
	200	100	0,0048	1,0497	1000
	200	200	0,0051	1,1080	1000
	200	300	0,0052	1,1486	1000
	200	400	0,0055	1,2054	1000
	200	500	0,0058	1,2830	1000
	300	100	0,0057	1,2465	1000
	300	200	0,0060	1,3137	1000
	300	300	0,0063	1,3798	1000
	300	400	0,0067	1,4626	1000
	300	500	0,0071	1,5671	1000
	400	100	0,0066	1,4434	1000
	400	200	0,0070	1,5450	1000
28˚	400	300	0,0075	1,6373	1000
	400	400	0,0080	1,7551	1000
	400	500	0,0087	1,9078	1000
	500	100	0,0076	1,6747	1000
	500	200	0,0081	1,7837	1000
	500	300	0,0086	1,8913	1000
	500	400	0,0093	2,0314	1000
	500	500	0,0102	2,2387	1000
	600	100	0,0088	1,9415	1000
	600	200	0,0094	2,0697	1000
	600	300	0,0103	2,2618	1000
	600	400	0,0112	2,4651	1000
	600	400	0,0130	2,8492	1000

A. 15 Tabel hasil pengamatan sudut kemiringan sudu 18°

Variasi sudut	Putaran (n)	Beban	Daya air (N_A)	Torsi (M)	Kecepatan sudut (ω)	Daya turbin (N_T)	Efisiensi turbin (η_T)
	(rpm)	(gram)	(watt)	(N.m)	(rad/s)	(watt)	(%)
	200	100	1,4014	0,0083	20,9333	0,1746	12,4559
	200	200	1,5589	0,0167	20,9333	0,3491	22,3946
	200	300	1,8079	0,0250	20,9333	0,5237	28,9656
	200	400	2,0849	0,0334	20,9333	0,6982	33,4889
	200	500	2,5258	0,0417	20,9333	0,8728	34,5536
	300	100	2,2296	0,0083	31,4000	0,2618	11,7431
	300	200	2,4557	0,0167	31,4000	0,5237	21,3245
	300	300	2,7530	0,0250	31,4000	0,7855	28,5318
	300	400	3,2961	0,0334	31,4000	1,0473	31,774
	300	500	4,1962	0,0417	31,4000	1,3091	31,1987
	400	100	3,1963	0,0083	41,8667	0,3491	10,9223
	400	200	3,7400	0,0167	41,8667	0,6982	18,6687
18°	400	300	4,2673	0,0250	41,8667	1,0473	24,543
	400	400	4,8985	0,0334	41,8667	1,3964	28,507
	400	500	6,3392	0,0417	41,8667	1,7455	27,5353
	500	100	4,3400	0,0083	52,3333	0,4364	10,0548
	500	200	5,3575	0,0167	52,3333	0,8728	16,2906
	500	300	6,3392	0,0250	52,3333	1,3091	20,6515
	500	400	7,7331	0,0334	52,3333	1,7455	22,5722
	500	500	10,0022	0,0417	52,3333	2,1819	21,8142
	600	100	6,4627	0,0083	62,8000	0,5237	8,1027
	600	200	8,5853	0,0167	62,8000	1,0473	12,199
	600	300	10,2295	0,0250	62,8000	1,571	15,3572
	600	400	12,3220	0,0334	62,8000	2,0946	16,9991
	600	500	16,6792	0,0417	62,8000	2,6183	15,6979

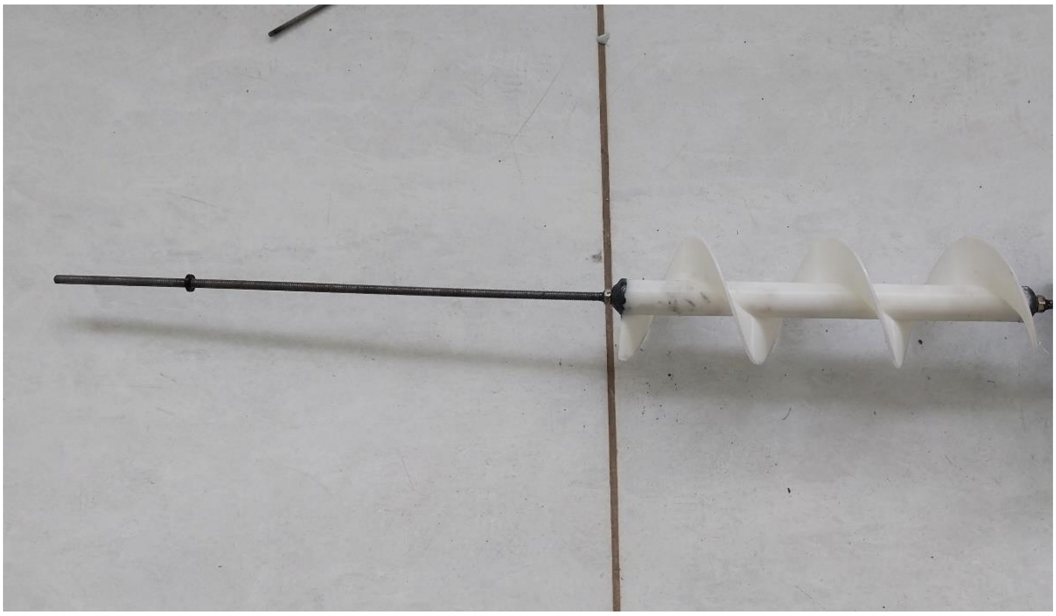
A. 16 Tabel hasil pengamatan sudut kemiringan sudu 23°

Variasi sudut	Putaran (n)	Beban	Daya air (N_A)	Torsi (M)	Kecepatan sudut (ω)	Daya turbin (N_T)	Efisiensi turbin (η_T)
	(rpm)	(gram)	(watt)	(N.m)	(rad/s)	(watt)	(%)
	200	100	1,9273	0,0083	20,9333	0,1746	9,0569
	200	200	2,1996	0,0167	20,9333	0,3491	15,8710
	200	300	2,4557	0,0250	20,9333	0,5237	21,3245
	200	400	2,7530	0,0334	20,9333	0,6982	25,3616
	200	500	3,2961	0,0417	20,9333	0,8728	26,4783
	300	100	3,1004	0,0083	31,4000	0,2618	8,4451
	300	200	3,6803	0,0167	31,4000	0,5237	14,2286
	300	300	4,1962	0,0250	31,4000	0,7855	18,7192
	300	400	4,8131	0,0334	31,4000	1,0473	21,7598
	300	500	5,9871	0,0417	31,4000	1,3091	21,8659
	400	100	4,5684	0,0083	41,8667	0,3491	7,6418
	400	200	5,2612	0,0167	41,8667	0,6982	13,2709
23°	400	300	6,2189	0,0250	41,8667	1,0473	16,8409
	400	400	7,4238	0,0334	41,8667	1,3964	18,8101
	400	500	9,7816	0,0417	41,8667	1,7455	17,8450
	500	100	6,5894	0,0083	52,3333	0,4364	6,6224
	500	200	7,5763	0,0167	52,3333	0,8728	11,5196
	500	300	8,9612	0,0250	52,3333	1,3091	14,6090
	500	400	11,2109	0,0334	52,3333	1,7455	15,5699
	500	500	15,0263	0,0417	52,3333	2,1819	14,5206
	600	100	10,9542	0,0083	62,8000	0,5237	4,7804
	600	200	12,6225	0,0167	62,8000	1,0473	8,2972
	600	300	14,6475	0,0250	62,8000	1,5710	10,7252
	600	400	18,5837	0,0334	62,8000	2,0946	11,2714
	600	500	26,3691	0,0417	62,8000	2,6183	9,9294

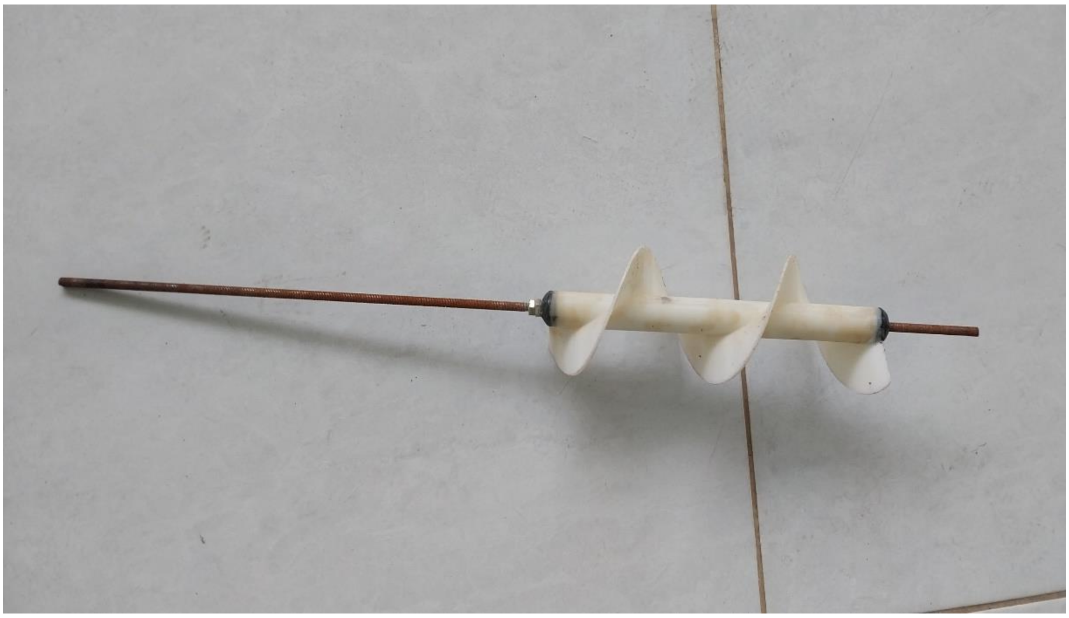
A. 17 Tabel hasil pengamatan sudut kemiringan sudu 28°

Variasi sudut	Putaran (n)	Beban	Daya air (N_A)	Torsi (M)	Kecepatan sudut (ω)	Daya turbin (N_T)	Efisiensi turbin (η_T)
	(rpm)	(gram)	(watt)	(N.m)	(rad/s)	(watt)	(%)
	200	100	2,6362	0,0083	20,9333	0,1746	6,6215
	200	200	3,1004	0,0167	20,9333	0,3491	11,2601
	200	300	3,4539	0,0250	20,9333	0,5237	15,1613
	200	400	3,9921	0,0334	20,9333	0,6982	17,4900
	200	500	4,8131	0,0417	20,9333	0,8728	18,1332
	300	100	4,4144	0,0083	31,4000	0,2618	5,9312
	300	200	5,1673	0,0167	31,4000	0,5237	10,1341
	300	300	5,9871	0,0250	31,4000	0,7855	13,1196
	300	400	7,1308	0,0334	31,4000	1,0473	14,6873
	300	500	8,7705	0,0417	31,4000	1,3091	14,9266
	400	100	6,8530	0,0083	41,8667	0,3491	5,0942
	400	200	8,4052	0,0167	41,8667	0,6982	8,3069
23°	400	300	10,0022	0,0250	41,8667	1,0473	10,4708
	400	400	12,3220	0,0334	41,8667	1,3964	11,3328
	400	500	15,8240	0,0417	41,8667	1,7455	11,0309
	500	100	10,7053	0,0083	52,3333	0,4364	4,0763
	500	200	12,9329	0,0167	52,3333	0,8728	6,7484
	500	300	15,4183	0,0250	52,3333	1,3091	8,4908
	500	400	19,1047	0,0334	52,3333	1,7455	9,1366
	500	500	25,5701	0,0417	52,3333	2,1819	8,5330
	600	100	16,6792	0,0083	62,8000	0,5237	3,1396
	600	200	20,2066	0,0167	62,8000	1,0473	5,1830
	600	300	26,3691	0,0250	62,8000	1,5710	5,9576
	600	400	34,1382	0,0334	62,8000	2,0946	6,1357
	600	500	52,7155	0,0417	62,8000	2,6183	4,9668

LAMPIRAN B



Gambar variasi sudut kemiringan sudu 18°



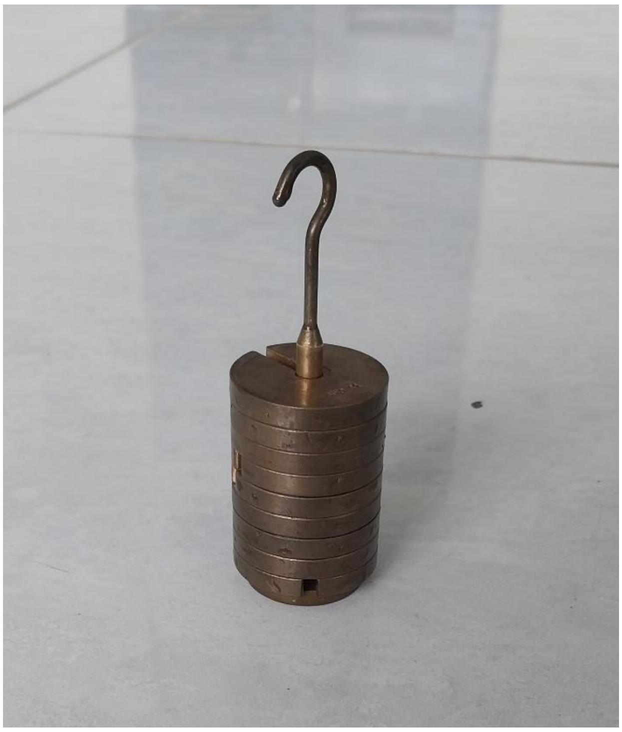
Gambar variasi sudut kemiringan sudu 23°

Gambar variasi sudut kemiringan sudu 28°

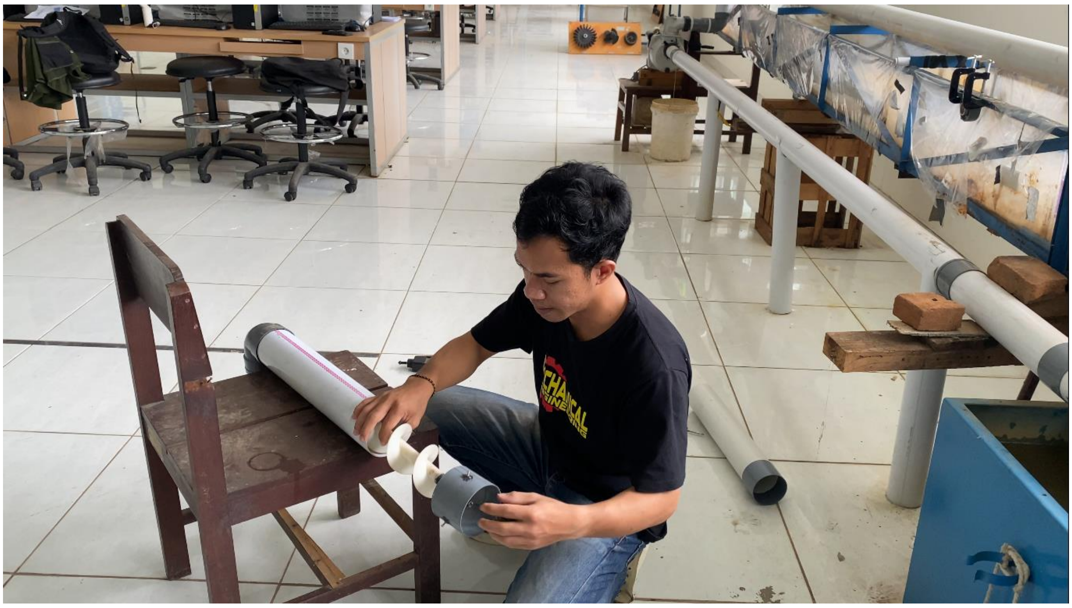

Gambar instalasi alat pengujian

Gambar rumah turbin

Gambar pompa

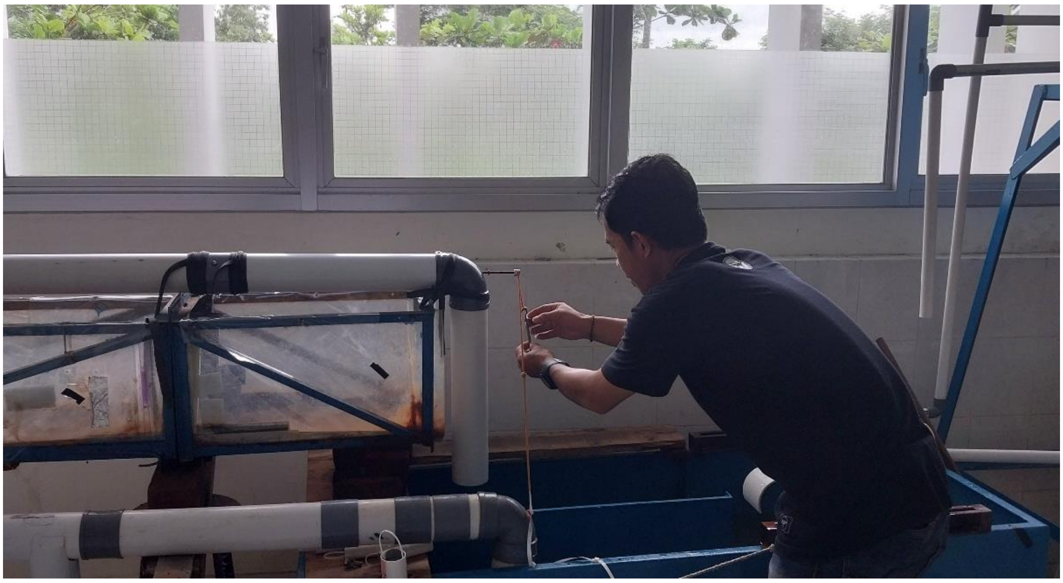


Gambar beban bertingkat



gambar pemasangan turbin ke dalam pipa 3 inch

Proses pemasang rumah turbin pada alat pengujian



gambar pemasangan beban bertingkat

gambar kalibrasi alat pengujian

gambar pengukuran kecepatan putaran turbin menggunakan tacometer

gambar pengukuran debit air

Gambar tacometer untuk pengambilan data kecepatan (rpm)

Gambar stopwatch digunakan untuk mengambil data waktu

Lampiran C

1. JURNAL

Effect Of Rotation On The Characteristic Of An Archimedes Screw Turbine In A Closed Channel

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Abstract- Renewable energy is a clean energy resource that is rapidly becoming popular worldwide to reduce dependence on fossil fuels. Hydroelectric power plants use energy from water flow, such as rivers, irrigation canals, and water distribution systems. This research uses the Archimedes screw water turbine model in a closed channel with a blade inclination angle of 23°. The method used is experimental with 5 levels of turbine rotation, namely 200 rpm, 300 rpm, 400 rpm, 500 rpm, and 600 rpm, and giving a load at each rotation, namely 100 grams, 300 grams, and 500 grams. At 200 rpm, the optimum efficiency reaches a peak of 20% with a turbine power of 1.5 watts. At 600 rpm, the power generated continued to increase, but the efficiency decreased, especially at lighter loads.

Keywords- Archimedes screw; efficiency; turbine power; turbine blade; rotation.

1. Introduction

The utilization of renewable energy sources is growing in various parts of the world [1]. Renewable energy has been recognized as an important part of efforts towards sustainable development and can answer a number of pressing global challenges [2]. Renewable energy is a clean energy resource rapidly becoming popular worldwide to reduce dependence on fossil fuel-based technologies [3]. The role of renewable energy is expected to achieve a sustainable future, with the hope that the target of 11% can reach 28% by 2025 of all energy users. [4]. The demand for renewable energy has significantly increased in recent years, as many facilities already use renewable energy instead of conventional energy [5]. Power generation from available Renewable Energy sources can gradually replace conventional power generation. RES has many advantages, including being environmentally friendly and safe, producing almost no emissions, and being installed in various locations using local resources and smaller investments [6]. Major renewable energy sources such as solar and wind energy are mostly free and naturally available; however, these sources can be unstable and unpredictable, reducing their reliability. Additionally, the amount of energy available from each source varies depending on location but can be estimated based on historical meteorological data for a given area. Combining two or three renewable energy sources can improve the overall reliability of the RES. In addition, energy storage technologies can be used to store excess energy when renewable sources are unavailable, thus increasing the dispatchability of the RES system. According to the International Energy Agency (IEA), by 2025, electrical energy generated from renewable energy sources will surpass electrical energy generated from conventional energy. Moreover, about 33% of the total global electrical energy production is estimated to come from renewable energy, with more than half coming from hydropower [7].

Electricity is an important energy source for the latest innovative technologies worldwide and is considered an indispensable factor in nation-building. Although the process of electricity generation is complex, electricity consumers seem to have immediate access to the energy. Most national grids rely on conventional power plants, such as steam turbines and gas-based power plants, which have operated for the past few decades. These power plants mainly use primary energy resources such as natural gas or heavy oil, and the power they generate causes greenhouse gas emissions and severe environmental damage [8]. Hydropower is the world's largest clean source of electrical energy, providing 1.25 times more clean energy than wind and solar energy, and has the flexibility that neither of them possesses [9]. Hydropower, or hydroelectricity, is one of the oldest and largest renewable energy sources, using energy from water flows such as rivers, irrigation canals, and water distribution systems to generate electricity [10]. In addition, affordable operation and maintenance costs, as well as technologies that support stable and flexible operation, provide higher efficiency and longer operational life [11]. Hydropower plants provide several additional advantages in addition to being fossil fuel-free power generation, which other renewable energy sources such as wind and solar power plants cannot provide [12]. Hydropower renewable energy is not dependent on weather changes as well as environmentally friendly energy [13]. Hydropower technology is a clean, efficient and reliable source of energy. In addition, the production cost is cheaper. In producing electricity from hydropower, we usually have a dam to regulate the water [14].

Small-scale power generation (picohydro) has significant potential by utilizing small water resources, including streams, man-made canals, and irrigation systems [15]. The electricity generated by pico hydro is able to provide power to rural communities or villages with about 30 households that only need a small amount of electricity, such as light bulbs, radios, TVs, and other appliances. Therefore, pico hydro can improve residents' living standards in remote areas worldwide. Pico hydro technology is easy to use and maintain, making it attractive to many professionals and non-professionals interested in generating electricity from renewable resources. As a result, interest in the research and application of pico hydro systems is proliferating and is of great importance to many developing and less developed countries [16]. The pico hydro production process does not require a large area or location and does not disturb the community around the power plant construction site [17]. The pico hydroelectric generator can produce electricity with a less than 5 kW capacity. The designed pico hydro must have several criteria, including river water flow, and the location area must meet the requirements for using pico hydro. The turbine is one of the most important components in the utilization of pico hydro.

The Archimedes screw is also known as one of the earliest hydraulic machines (Archimedean or hydrodynamic screw) [18]. Archimedes screws have been utilized for various purposes, including low-lying drainage systems, wastewater treatment, and irrigation. In recent times, these screws have also begun to be widely used as hydropower turbines [19]. Archimedes screw turbines or turbines with Archimedean-type screw design have been used to harness the kinetic energy contained in water flow. Archimedes screw turbines are used as a small-scale hydropower technology to convert into electric power [20]. In addition, the Archimedes screw turbine is environmentally friendly, does not damage the habitat of aquatic fauna, and the cost of manufacturing is low [21]. Archimedes screw turbines have high efficiency in operating low head and slow water flow, and can be installed and operated in various locations such as rivers, waterways, steep slopes, dams, and areas with different currents [22]. An Archimedes screw is formed of several helices connected to a central cylindrical shaft in a closed inclined trough. There is a small gap between the trough and the screw, which allows free rotation of the screw as well as variable rotation and water discharge [23]. The basic principle of the Archimedes screw turbine is to utilize the kinetic energy produced by water into mechanical energy, which is used to rotate a generator to produce electrical energy [23].

In Archimedes crew turbine research, researchers use several methods, including experimental methods and MATLAB simulations using mathematical equations. The results of experimental method research conducted by previous researchers show that power increases with increasing flow, while efficiency generally decreases with increasing flow [24]. In addition, other studies have also produced similar results where turbine efficiency decreases as the angle α increases and the resulting turbine power is high [25]. MATLAB simulation results show that the turbine rotational speed rotational speed and output power increase with an increase in the input flow rate to the turbine [22]. To achieve optimum turbine power and optimum turbine efficiency, the Archimedes screw turbine is given a constant rotation with load variations. The purpose of this research is to determine the effect of Archimedes screw turbine rotation on closed channels.

2. Methodology

This study uses the Archimedes screw water turbine model in a closed channel with a blade inclination angle of 23 °. The method used is experimental with 5 levels of turbine rotation, namely 200 rpm, 300 rpm, 400 rpm, 500 rpm, and 600 rpm and giving a load at each rotation, namely a load of 100 grams, 300 grams, and 500 grams. the size of the closed channel pipe used is 89 mm outside diameter and 82 mm inside diameter. further can be seen in the fig. 1.

This research covers the effect of rotation on the characteristic of the Archimedes screw turbine in a closed channel focused on 5 levels of rotation, with each rotation given 3 different load levels. Based on previous research conducted by Djun et al. [16]. These turbines are designed to address increasing environmental concerns and aim to reduce project costs. Advances in hydropower technology have developed new turbines for very low water levels or even on horizontal planes [26].

The turbine thread in this study was made using 3D printing; this was done so that the threads made were more precise, and the material used was plastic (acetonitrile butadiene Styrene). The thread length is 250 mm, the inner diameter is 22 mm and the outer diameter is 79 mm, the size of the turbine shaft is 700 mm. The Archimedes screw turbine research object can be seen in the fig. 2.

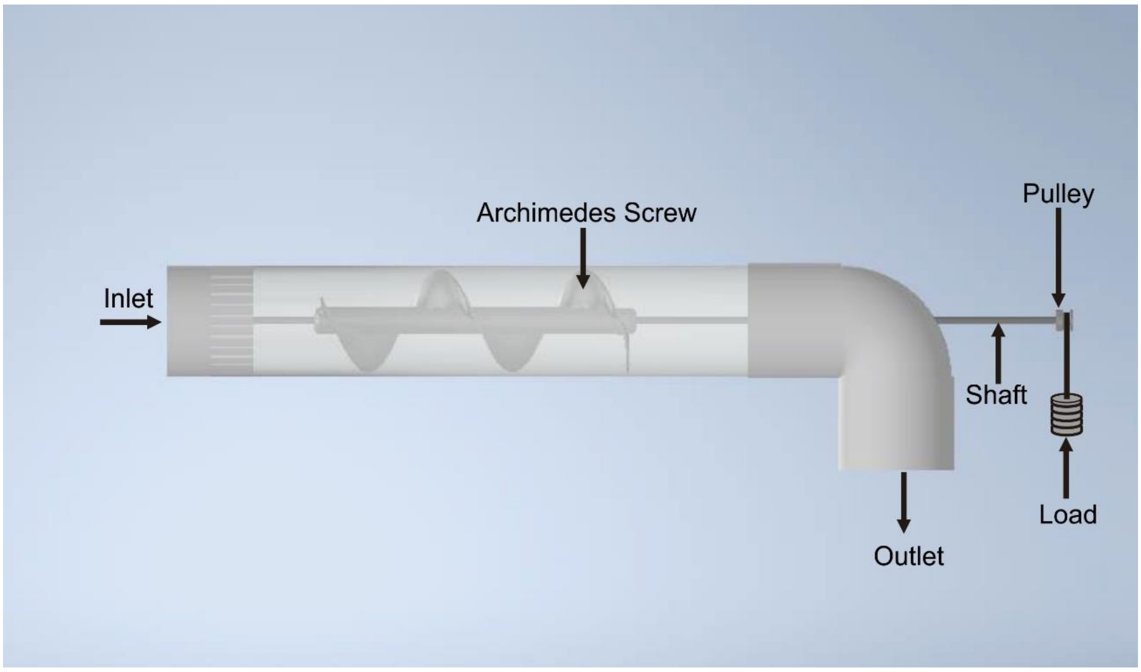

Figure 1. Sketch of Archimedes screw turbine in closed channel.

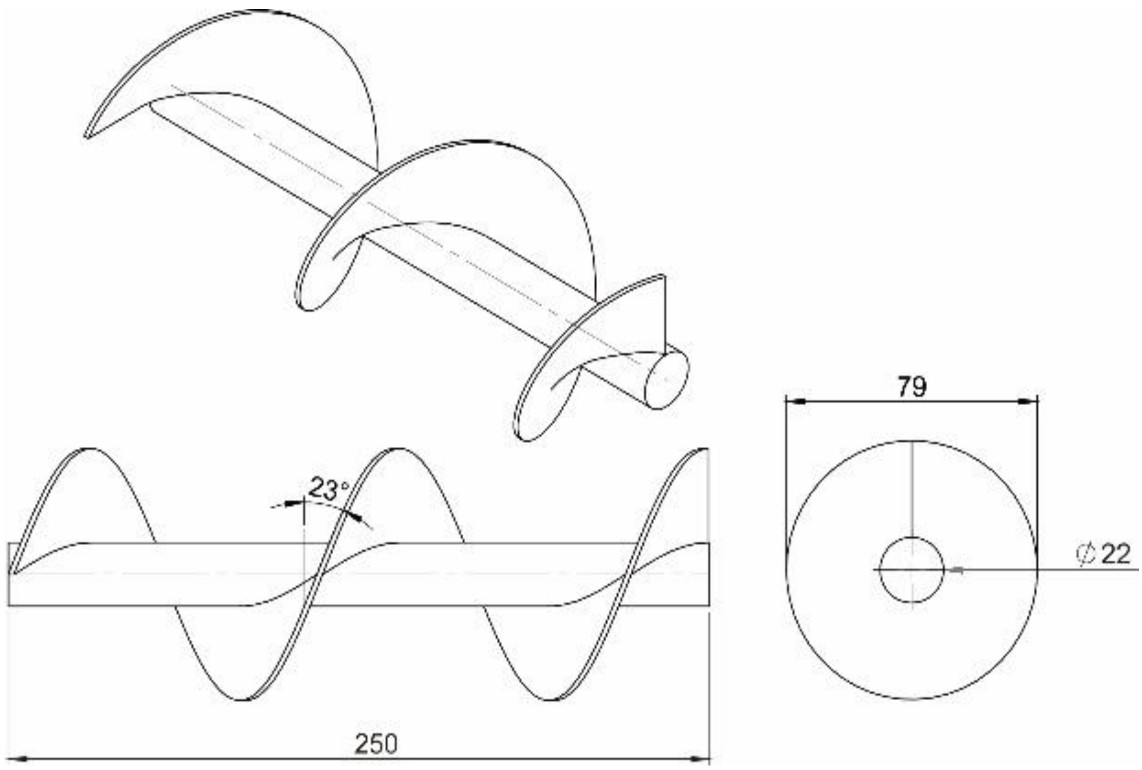

Figure 2. Archimedes screw turbine with blade tilt angle 23° .

After installation is considered complete the pump is turned on to find out leaks in the water line and check the turbine rotation by installing a research object on the waterways and checking the turbine rotation by installing the research object in the picture. picture. 3 to find out whether the turbine rotation is suitable for data collection or not. data collection or not. If, in the testing process, there are installations that are experiencing interference or do not function, repairs are made to the test on the test equipment and then collect data again. If considered appropriate, then the next stage is the data collection process. In the process of measuring water discharge, a container of 10 liters is prepared to know the volume of water flowing into the turbine per unit time with the turbine that has been given loading. turbine that has been given loading. In the process of taking data, the load is hung on the pulli that has been installed at the end of the turbine shaft. Testing scheme The experimental testing scheme carried out can be seen in the figure. 3 In each load that Each load tested is given 3 different levels of rotation.

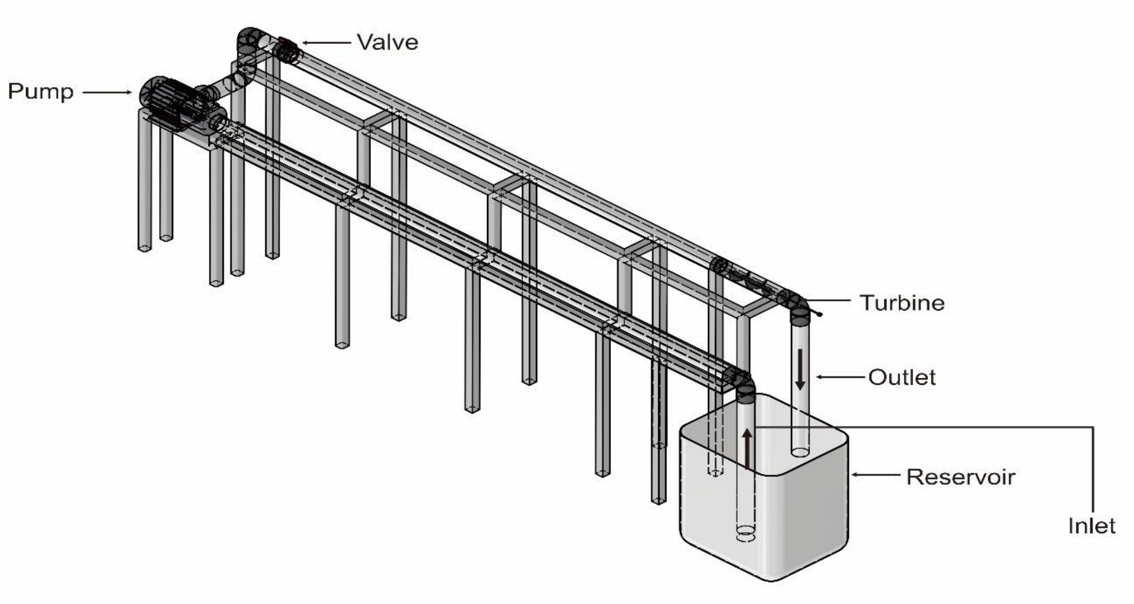

Figure 3. The testing Schematic.

To find out the turbine power is generated by the rotating moment generated by the turbine, where the energy coming from the water drives the turbine. Calculation of Turbine Power using Equation 1. How much water kinetic energy can drive a turbine is called efficiency. In determining the efficiency of the turbine, equation 2 is used.

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$$N_T = \tau.\omega \tag{1}$$

$$\eta_{\tau} = \frac{N_T}{N_A}.100\% \tag{2}$$

3. Result and Discussions

The relationship between turbine rotation (rpm) and turbine power (watt) at 3 different load levels of 100 grams, 300 grams, and 500 grams. in fig. 4 shows that the turbine power increases with the increase in rpm and load applied to the turbine. The 100-gram load at 600 rpm shows a relatively low increase in turbine power, with a maximum turbine power of 0.523 watts. At a load of 300 grams, showing a more significant growth, the turbine power reached about 1,570 watts at 600 rpm. The 500-gram load at 600 rpm showed the highest increase in power, reaching about 2.618 watts.

According to Archimedes' turbine theory, the efficiency of the turbine and the power generated are greatly affected by the rotation speed and the load. Increased load leads to increased power generated due to the greater force on the turbine blades, resulting in more mechanical work. Fig. 4 also shows that at higher rotation speeds, the energy generated increases linearly with increasing load. This is in line with the basic principle of the Archimedes turbine which utilizes the flow of water fluid to drive the turbine blades, where the increased force from heavier loads increases the torque and power of the turbine produced. Editor also informs authors about processes of submitted article by e-mail. Each author may also apply to Editor via online submission system to review papers related to their study areas. Peer review is a critical element of publication, and one of the major cornerstones of the scientific process. Peer Review serves two key functions:

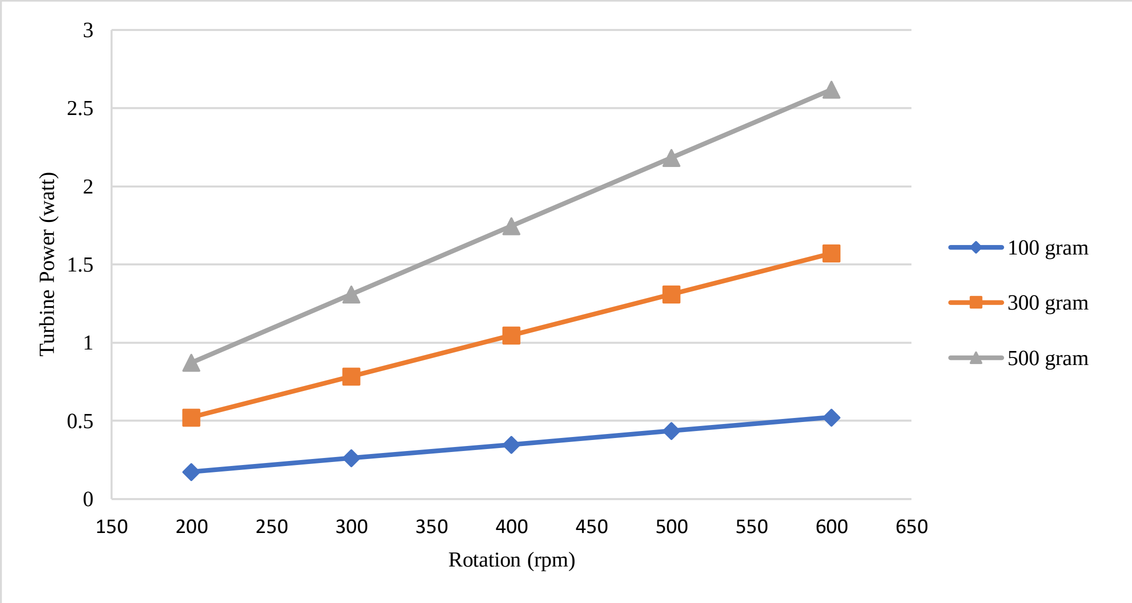

Figure 4. Relationship between rotation (rpm) and turbine power (watt) at 3 levels of load variation of blade inclination angle 23°

At 3 different load levels of 100 grams, 300 grams, and 500 grams. It can be seen that the efficiency of the turbine tends to decrease as the rotation increases. At each load weight, the efficiency is initially at the highest range of about 20 % for the 500-gram load, decreasing gradually to close to 3.76 % at 600 rpm for the 100-gram load. This indicates that at larger load weights, the Archimedes turbine is able to maintain a higher efficiency compared to lighter load masses. In Fig. 5, the difference in efficiency at various load weights shows how load weight affects turbine performance. Heavier loads tend to produce higher efficiencies at low revolutions as they gain more energy from the water flow. However, mechanical resistance and water turbulence increase at higher revolutions, leading to decreased efficiency. This is in accordance with the basic principles in Archimedes turbine design and operation, where there is an optimum point in turbine operation that maximizes efficiency.

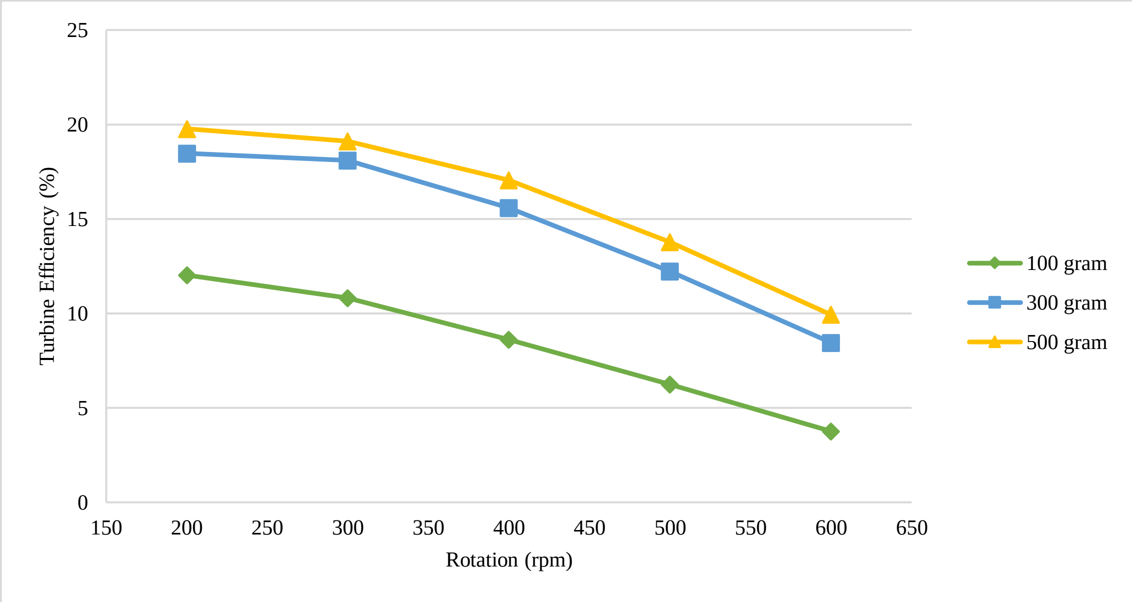

Figure 5. Relationship between rotation (rpm) and turbine efficiency (%) at 3 levels of load variation of blade tilt angle 23°

The relationship between rotation (rpm) and water discharge (Q) at 3 different load levels of 100 grams, 300 grams, and 500 grams can be seen in the figure. 6 In general, it can be seen that the water discharge increases with the increase in rotation at all loads. The 500-gram load shows the highest water discharge at every rotation, followed by 300-gram and 100-gram. At 600 rpm, the water discharge for the 500-gram load is close to 0.010 m^3/s, while for the 100-gram load, the water discharge only reaches about 0.007 m^3/s. This shows that the greater the load given to the turbine, the greater the water discharge produced.

In Fig. 6, the increase in water discharge with increasing rotation and load shows that the Archimedes turbine works more efficiently in moving water when given a larger load and higher rotation. This can be explained by the basic principle that a turbine, given a larger load, has a larger torque, which allows the turbine to move more water per revolution. In addition, higher revolutions increase the speed of water flow through the turbine blades, thereby increasing the water discharge. However, even though the water discharge increases, the turbine efficiency does not always follow the same pattern, as shown in the previous graph, where the efficiency decreases at higher revolutions. This indicates that although the turbine can deliver more water at high loads and speeds, factors such as turbulence and friction also increase, ultimately reducing the turbine's overall efficiency.

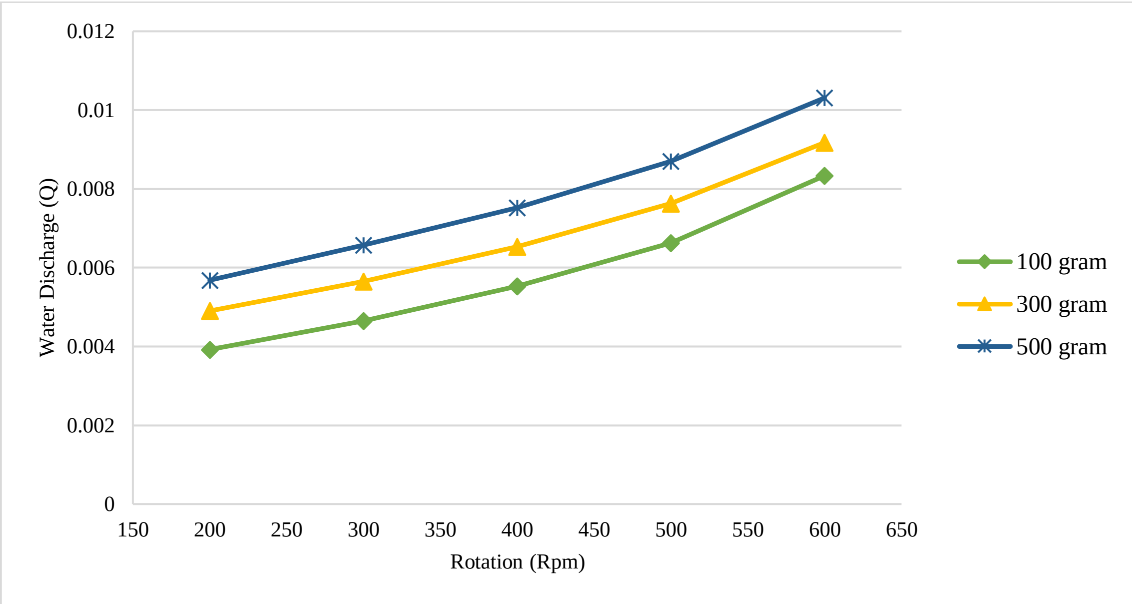

Figure 6. Relationship between rotation (rpm) and water discharge (Q) at 3 levels of load variation of blade tilt angle 23°

Fig. 7 shows the relationship between turbine power (watts) and Archimedes turbine efficiency (%) at various rotation speeds (rpm). It can be seen that the turbine efficiency varies based on the rotation speed and power generated. At 200 rpm, the optimum turbine efficiency increases to about 20% when the turbine power reaches about 1.5 watts before decreasing slightly. At 300 rpm, the optimum turbine efficiency is about 10% and increases significantly to a peak of about 22% at about 1.5 watts of power, indicating that the turbine works more efficiently at this speed than at 200 rpm. At 400 rpm, the efficiency starts at about 15% and peaks at about 20% before decreasing slightly as the power increases further.

At the higher speeds of 500 rpm and 600 rpm, it can be seen that the efficiency increases as the power increases until it reaches a peak before decreasing. At 500 rpm, the efficiency reaches about 20% at about 2 watts of power, while at 600 rpm, the efficiency reaches about 15% at the same power. Archimedes' turbine theory states that a turbine's efficiency is determined by various factors, including the rotation speed, the design of the turbine blades, and the fluid flow that drives them. Fig. 7 shows that there is an optimal rotation speed at which the turbine achieves maximum efficiency.

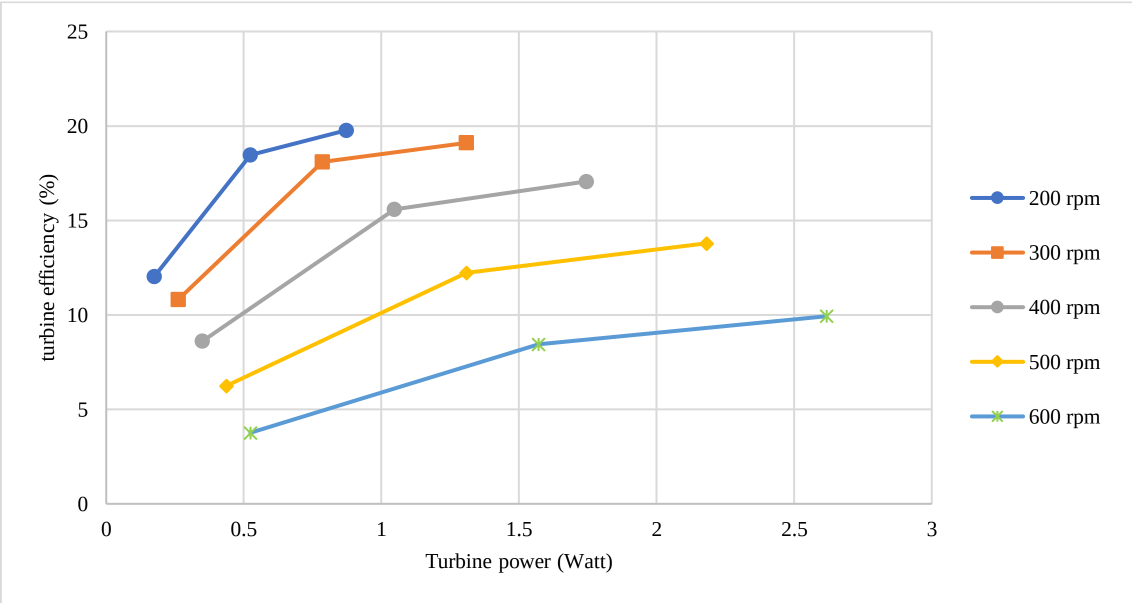

Figure 6. Relationship between turbine power (Watt) and turbine efficiency (%) at 3 levels of load variation of blade inclination angle 23°

The efficiency of the turbine and the power generated are greatly affected by the rotation speed and the load. Increased load leads to increased power generated due to the greater force on the turbine blades, resulting in more mechanical work. Archimedes turbines are able to maintain higher efficiency at lighter loads. The difference in efficiency under load weight shows how load weight affects turbine performance. A heavier load tends to result in higher efficiency at low revolutions as it gains more energy from the water flow. However, mechanical resistance and water turbulence increase at higher revolutions, leading to decreased efficiency.

4. Conclusion

From the study of the effect of rotation on the characteristics of the Archimedes screw turbine at an inclination angle of 23°, it can be concluded that the rotation speed and load have a significant effect on the power and efficiency of the Archimedes turbine. At 200 rpm, the efficiency peaks at about 20% at 1.5 watts of power but decreases as the power increases. At 600 rpm, the power generated increases, but the efficiency decreases, especially at lighter loads. Larger loads, such as 500 grams, tend to result in higher efficiency at low revolutions, but efficiency decreases at higher revolutions due to increased mechanical drag and turbulence.

Acknowledgements

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2. Prosiding

The Effect of Load on the Characteristics of an Archimedes Screw Turbine in a Closed Channel

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Abstract. Faced with global challenges such as climate change, environmental risks and resource constraints, renewable energy is a solution in reducing the use of fossil fuels. Among the various technologies used to generate power from water, small-scale hydropower technology is becoming a popular choice due to its ease of access and wider availability in various locations. This study aims to determine the effect of load on the characterisitc of the Archimedes screw turbine in a closed channel at a tilt angle of the turbine blade 18° with 5 levels of load namely 100 grams, 200 grams, 300 grams, 400 grams, and 500 grams and provide 3 levels of rotation at each load namely 200, 400 and 600 rpm. At a load of 500 grams with a speed of 600 rpm, the resulting water power is 14.648 watts. Turbine power also increases with load and rotation speed. At a load of 500 grams with a rotation of 600 rpm, the optimum turbine power produced was 2.618 watts. Turbine efficiency increases with load up to the optimum point, then there is a decrease in efficiency when reaching the peak of turbine performance. At a load of 400 grams with a rotation speed of 200 rpm, the optimum efficiency of the turbine was 34.386%.

INTRODUCTION

Facing global challenges such as climate change, environmental risks, and limited resources, renewable energy is a solution in reducing the use of fossil fuels [1],[2]. The utilisation of renewable energy sources, such as hydropower, is growing in various parts of the world [3],[4]. Among the various technologies used to generate power from water, small-scale hydropower technology is becoming a popular choice due to its ease of access and wider availability in various locations [5]. Technical innovations make ultra-low head small-scale hydropower plants more attractive from a technical point of view [6],[7]. Small hydropower plants are one of the renewable energy solutions. This is due to their relatively fast construction process and lower project development costs when compared to large-scale hydropower plants [8]. Worldwide, hydropower is considered one of the most established forms of renewable energy and plays a central role in the provision of electricity in more than 160 countries [9].

Hydropower is one of the oldest and largest renewable energy sources [10]. Several countries have started to adopt small-scale hydropower significantly [11]. There are various types of small hydro turbines in use, such as Archimedes screw turbines, Kaplan, and Francis [12].

The use of Archimedes screw turbines is a relatively new innovation in power generation [13]. Screw turbines are an ideal option for conditions with low head differences and a wide variety of water flows [14]. Archimedes screw turbines or turbines with Archimedean-type screw design have been used to harness the kinetic energy contained in water flow [15],[16]. An Archimedes screw is formed of several helices connected to a central cylindrical shaft in a closed inclined trough. There is a small gap between the trough and the screw, which allows free rotation for the screw [17].

METHODOLOGY

This research uses experimental methods with a focus on the Archimedes screw turbine in a closed channel. The blade of the Archimedes screw turbine is determined at the blade tilt angle 18°. Tests were carried out at 5 load levels namely 100 grams, 200 grams, 300 grams, 400 grams and 500 grams, and each load level was tested at three different rotation levels namely 200 rpm, 400 rpm, and 600 rpm can be seen in the figure. 1 This study aims to evaluate the performance of turbines in closed channels at varying operating conditions, by measuring parameters such as efficiency [18]. In addition, research conducted by Neeraj et al on the efficiency of the Archimedes screw turbine [17].

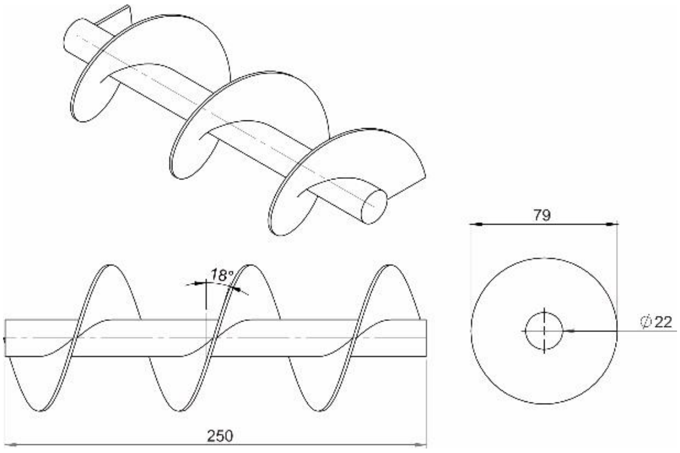

FIGURE 1. Archimedes screw turbine with blade inclination angle 18°

$$Re = \frac{U.D}{\upsilon} \tag{1}$$

This research uses a pipe as a closed channel that has an outer diameter of 89 mm and an inner diameter of 82 mm. The turbine thread in this study was made using 3D printing, this was done so that the threads made were more precise, and the material used was ABS (Acetonitrile Butadine Styrene) plastic. The length of the thread is 250 mm, the inner diameter is 22 mm and the outer diameter is 79 mm, the length of the turbine shaft is 700 mm in Figure.2.

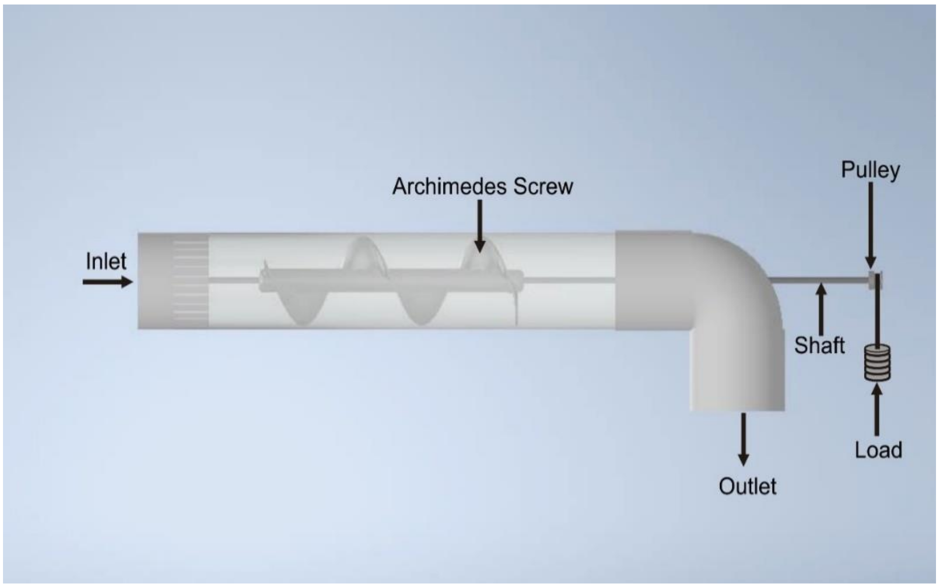

FIGURE 2. Sketch of an Archimedes screw turbine in a closed channel

After the installation is considered complete, the pump is turned on to find out leaks in the water line and check the turbine rotation by installing the research object in fig. 3 to find out whether the turbine rotation is suitable for data collection or not. If in the testing process there is an installation that is experiencing interference or does not function, repairs are made to the test equipment and then collect data again. If it is considered appropriate, the next stage is the data collection process. In the process of measuring water discharge, a container of 10 litres is prepared to determine the volume of water flowing into the turbine per unit time with the turbine that has been given loading. The experimental testing scheme carried out can be seen in the figure. 3 Each load tested is given 3 different rotation levels.

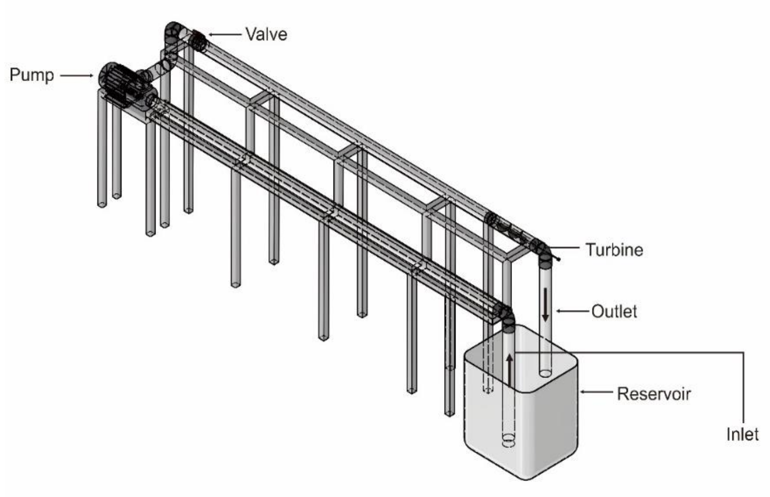

FIGURE 3. The testing Schematic

Turbine power is generated by the rotating moment generated by the turbine. Where the energy comes from the water that drives the turbine. Turbine power calculation using equation 1.

$$N_T = \tau.\omega \tag{1}$$

To find out how much water kinetic energy can drive a turbine is called efficiency. In determining the efficiency of the turbine the equation uses equation 2.

$$\eta_\tau = \frac{N_T}{N_A}.100\% \tag{2}$$

RESULTS AND DISCUSSION

Fig. 4 shows the relationship between load (grams) and water power (watts) at various rotation speeds (rpm) for an Archimedes turbine. The data in the graph includes three different rotation speeds of 200 rpm, 400 rpm and 600 rpm. It shows that at each rotation speed, the water power (wattage) increases as the load increases. At a rotation speed of 200 rpm, the water power increased slowly from about 0.840 (watts) at a load of 100 grams to 2.636 (watts) at a load of 500 grams. At a speed of 400 rpm, the water power increases from 2.230 (watts) at a load of 100 grams to 6.339 (watts) at a load of 500 grams.

The highest rotation speed, 600 rpm, showed the highest increase in water power. At a load of 100 grams the water power was 6.853 (watts) and increased to 14.648 (watts) at a load of 500 grams. The higher increase in water power at higher rotation speeds indicates that the efficiency of the Archimedes turbine in producing water power is more optimal at higher rotation speeds. This could be due to the greater increase in water momentum at higher rotation speeds, resulting in greater power.

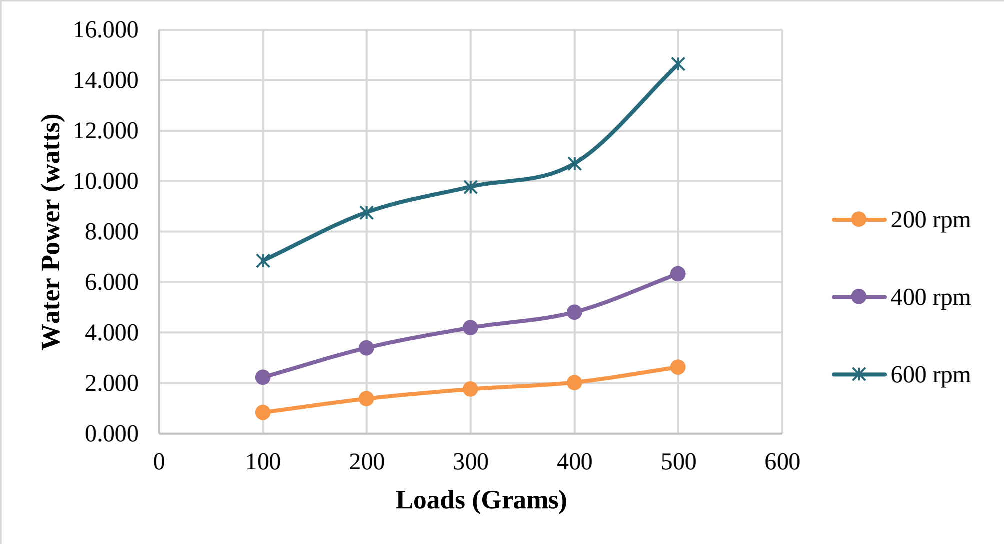

FIGURE 4. The relationship between load (grams) and water power (watts) at 3 levels of turbine rotation of blade inclination angle 18°

Fig. 5 relationship between load (grams) and turbine power (watts) with various rotation speeds (rpm) for the Archimedes turbine. It can be seen that at each rotation speed, the turbine power increases as the load increases. At a rotation speed of 200 rpm, the turbine power increases from 0.175 watts at a load of 100 grams to 0.873 watts at a load of 500 grams. At a speed of 400 rpm, the increase in turbine power was more significant, ranging from 0.349 watts at a load of 100 grams to 1.746 watts at a load of 500 grams. The highest rotation speed, 600 rpm, showed the most significant increase in turbine power. The turbine power was 0.524 watts at a load of 100 grams and continued to increase to 2.618 watts at a load of 500 grams.

attachedaaa The higher increase in turbine power at higher rotation speeds indicates that the efficiency of the Archimedes turbine in generating power increases with increasing rotation speed. Fig. 5 gives an overview of how variations in load and rotation speed affect the turbine power output of the Archimedes turbine.

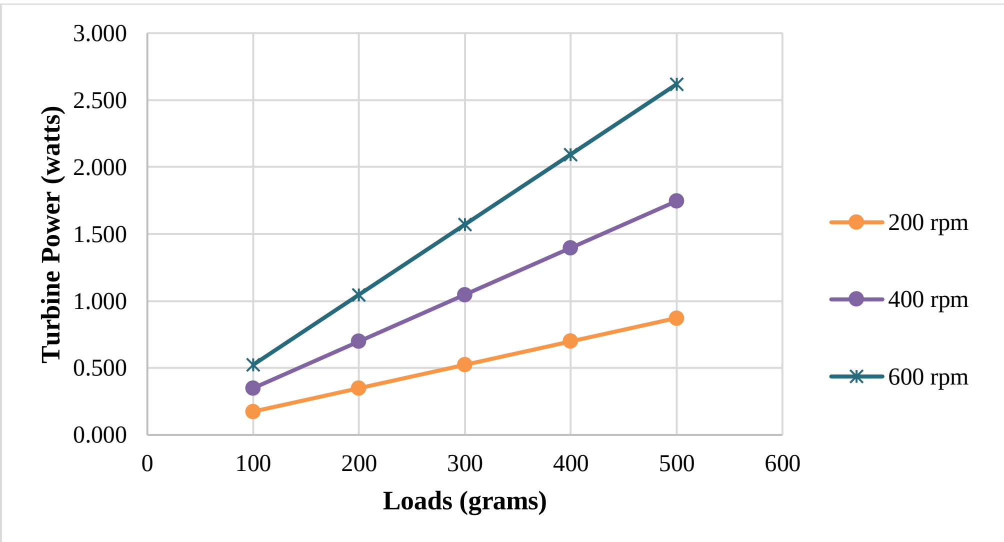

FIGURE 5. The relationship between load (grams) and turbine power (watts) at 3 levels of turbine rotation of blade inclination angle 18°

Fig. 6. it can be observed that the turbine efficiency increases with increasing load until it reaches the optimum point of turbine efficiency, after which the efficiency tends to decrease. At a rotation speed of 200 rpm, the turbine efficiency increases from about 20.782% at a load of 100 grams to reach the optimum point of turbine efficiency of 34.386% at a load of 400 grams, then decreases when the load reaches 500 grams. At a rotation speed of 400 rpm, the efficiency was initially 15.657 % at a load of 100 grams, increasing gradually until it reached the turbine optimum point of 29.013 % at a load of 400 grams, and then decreased. For a rotation speed of 600 rpm, the turbine efficiency starts from 7.641% at a load of 100 grams, increases to 16.061% at a load of 300 grams, but then shows a significant decrease in efficiency after reaching the optimum efficiency of the turbine. Fig. 6 shows that higher rotation speed does not always result in higher efficiency, especially at larger loads. This is due to various factors such as water flow turbulence or increased mechanical friction at higher rotation speeds. From the analysis of these graphs, it can be concluded that to achieve maximum efficiency, the rotation speed and load must be optimised. A rotation speed of 200 rpm shows a more stable and optimised efficiency performance compared to 400 rpm and 600 rpm.

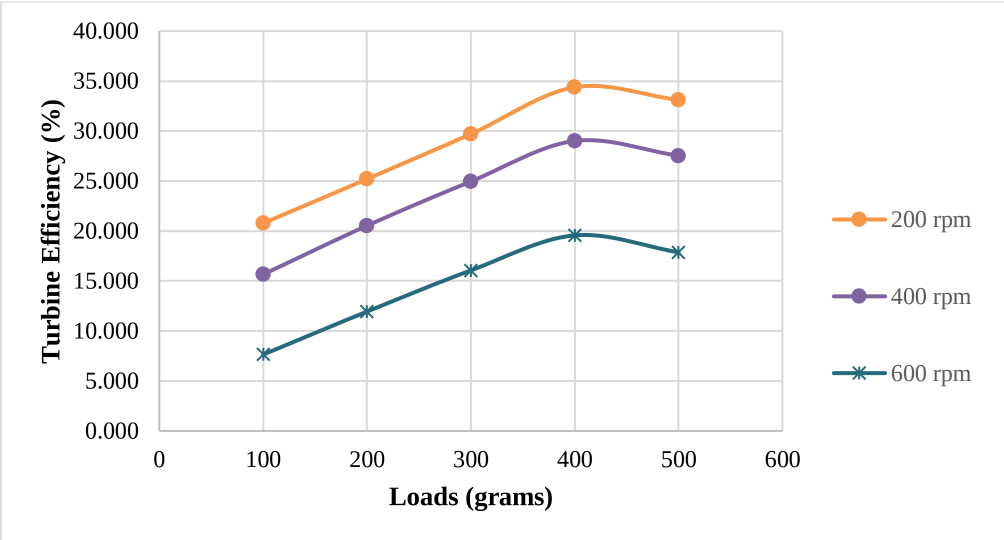

FIGURE 6. The relationship between water discharge (Q) and turbine efficiency (%) at 3 levels of turbine rotation of the blade tilt angle 18°

The relationship between water discharge (Q) and turbine power (watts) at loads of 100 grams, 200 grams, 300 grams, 400 grams, and 500 grams. Fig. 7 shows that with increasing water discharge, turbine power tends to increase for all tested load weights. At 100 grams, the turbine power starts from about 0.5 watts and increases to 1.5 watts when the water discharge increases from 0.0040 to 0.0080. Meanwhile, at 500 grams load, the turbine power starts from 0.5 watts and increases up to 2.5 watts with the same increase in water discharge.

It can be concluded that larger loads tend to produce higher turbine power at the same water discharge compared to smaller loads. Fig. 7 shows that increasing water discharge consistently increases turbine power, and larger loads can maximise the turbine power generated.

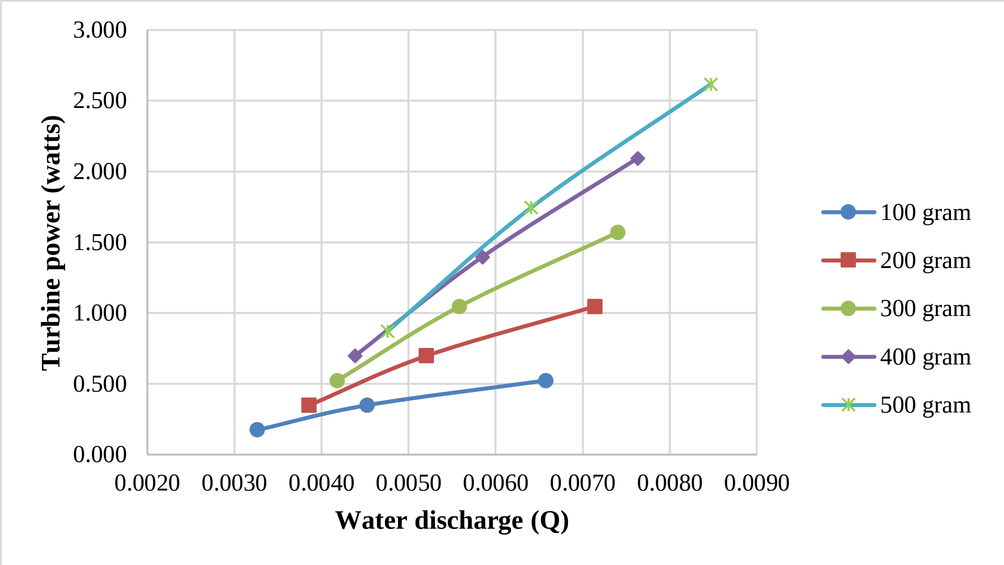

FIGURE 7. The relationship between water discharge (Q) and turbine power (watts) at 5 load levels of blade inclination angle 18°

Archimedes turbine performance is strongly influenced by load and rotation speed (rpm). At each rotation speed of 200 rpm, 400 rpm, and 600 rpm, the water discharge and turbine power increased with increasing load. Higher rotation speeds produce greater water discharge and turbine power.

Turbine efficiency is also affected by load and rotation speed. Turbine efficiency increases as the load increases until it reaches an optimum point, then there is a decrease in turbine efficiency when reaching turbine performance. Higher rotation speeds do not always result in higher efficiency, especially at larger loads, due to factors such as water flow turbulence and increased mechanical friction. Therefore, to achieve maximum efficiency, the rotation speed and load must be optimised, with 200 rpm showing a more stable and optimal efficiency performance compared to 400 rpm and 600 rpm.

CONCLUSION

The effect of load on the characterisitc of the Archimedes screw turbine in a closed channel at an angle of inclination of the turbine blade 18° with 5 levels of load namely 100, 200, 300, 400, and 500 grams and 3 levels of rotation namely 200, 400 and 600 rpm. From the data obtained, it can be concluded that turbine efficiency, turbine power, and water discharge are strongly influenced by the rotation speed and load applied. At a load of 500 grams with a speed of 600 rpm, the water power produced was 14.648 watts. Turbine power also increases with load and rotation speed. At a load of 500 grams with a rotation of 600 rpm, the optimum turbine power produced was 2.618 watts. Turbine efficiency increases with load up to the optimum point, then there is a decrease in efficiency when reaching the peak of turbine performance. At a load of 400 grams with a rotation speed of 200 rpm, the optimum efficiency of the turbine was 34.386%.

Overall, the turbine operates most efficiently at lower rotation speeds and medium loads, while power and water discharge increase with increasing load and rotation speed. Optimisation of turbine operation requires precise settings to be within the peak efficiency range for best performance.

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