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CONSTRUCTION AND TESTING OF A CROSSFLOW MICRO-HYDROPOWER TURBINE

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ABSTRACT: *Micro-hydropower technology has established contributions in the provision of modern energy for rural communities of several developing countries where the resources are available. However, Nigeria has not been able to utilized these resources to combat the shortage of electrical energy in most of its rural communities where the potentials had already been identified. In order to successfully implement the development of micro hydropower for rural energy supply, certain measures need to be put in place. This research proffered some of the solutions by identifying and developing simplified technology for the construction of micro hydro turbines with high efficiency and low cost. This research work comprises of experimental studies of the cross-flow turbineconducted at Ahmadu Bello University (ABU), Zaria. A dedicated test rig was designed and constructed using existing facility at the Boiler Room of the Heat Engine laboratory of the Department of Mechanical Engineering, ABU, Zaria. Locally sourced materials and technology were used for the construction in order to ensure easy replication and maintenance. Two standard orifice plates were designed, developed and installed on the turbine supply pipeline for the purpose of measuring the differential pressure, hence the flowrate across the turbine. A Rope Brake dynamometer was also designed, constructed and installed on the turbine base for loading the turbine at various speeds. The existing pipeline that includes a 10Hp centrifugal pump was re-configured to include three additional portable centrifugal pumps operating in parallel, 3-, 4- and 6-inches pipe network, 6 and 4-inch butterfly valves and pressurized tank for simulating various pressure heads and flow.*

KEYWORDS: *Micro-hydropower, centrifugal pump,test rig, cross-flow turbine, orifice plates.*

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I. INTRODUCTION

Nigeria has the opportunity to increase access to electricity by developing its 18,600MW of large hydropower potentials (Muhammadu et al., 2014) and connecting the same to national grid. In addition, the 3500MW of small hydropower potentials which are distributed across the country are best suited for distributed generation (Kela et al., 2012). Harnessing these small hydropower resources will definitely increase access to electricity especially in the rural and disperse locations that are far away from the grid, which would reduce poverty and enhance quality of life (Osokoyaet al, 2013).

The survey of the status of hydropower development in Nigeria revealed an estimated 14,120 MW potential, this amount to 50800 GWh of electricity annually (IHA, 2018). An evaluated data from the River Basins Authorities discovered a total of forty-one feasible sites with potential capacities ranging from 5 to 5000 kW across the country. Yekinni et al. (2015) concluded in their studies of small hydropower that use of standardized equipment and uniform construction practice could significantly increase the reliability and speed up the growth of small hydropower. In a related study, Ohunakin et al. (2011) identified small scale hydropower as preference for remote off grid applications for rural dwellers; if net savings could be derived from the use of local materials and labour, and the development of local technology.

The National Agency for Science and Engineering Infrastructure (NASENI) has initiated the manufacturing of T15 crossflow turbine, and installed same in some sites across the Nigeria in collaboration with UNIDO (Awosope, 2014). However, if this effort could be supported with laboratory or field tests to characterize these turbines, as well as optimizing their configuration and improve their performance using CFD; such development could have brought about rapid development of local technology. It would also enable replication and significant cost reduction. Since the cost of electromechanical equipment in small hydropower may exceed 50% of the total cost.

II. METHODOLOGY

A. CONSTRUCTION OF THE TURBINE

The runner was constructed of two-side plate cut from mild steel flat bar. The nozzle curve and the blades cut from stainless steel plate of 3mm thickness and stainless-steel pipe of 76mm outer diameter and 2mm thickness. The shaft was made using stainless steel material and sections reduced to required size on lathe. The two side plates were gas-cut to size and turned on a lathe to the finished diameter after being welded to the flanges that would support them on the shaft as shown on Plate 1. The blades were slotted between the two side plates and welded. The adapter was made from 4mm mild steel plate folded and welded to a short pipe provide with Flanges to connect to the pipe and turbine nozzle as shown in Plate 3.1. Flanges to hold together the shafts for controlling the flow into the nozzle were fabricated as shown in Plate 1.

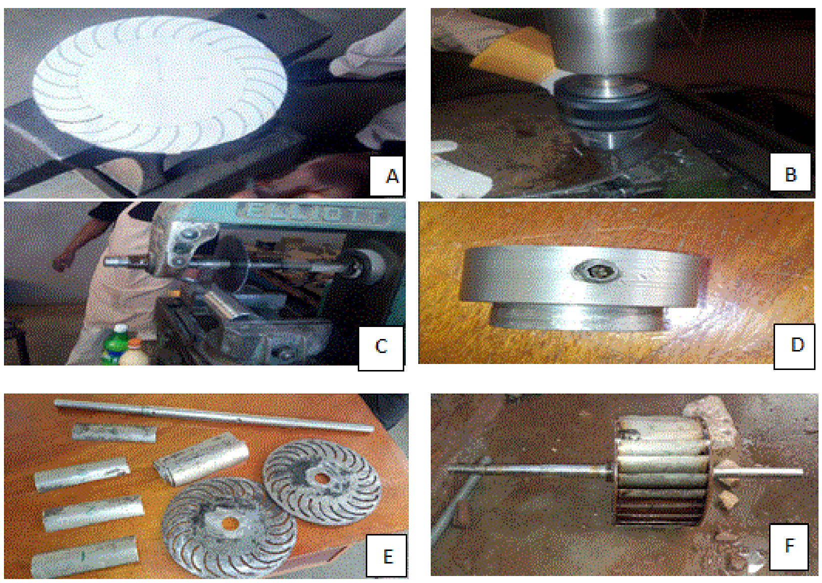
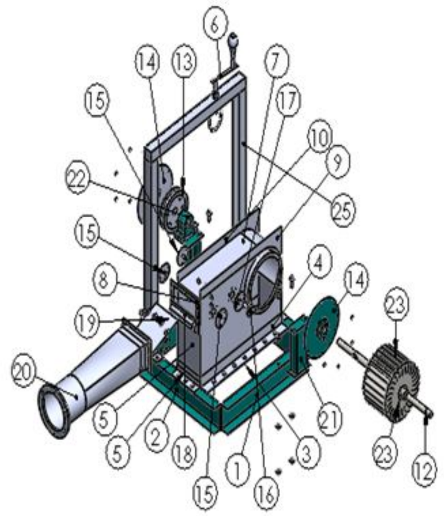


Plate 1. (A) Blade Holes Markings, (B) Blade Holes Cutting (C) Blade Cutting on Milling Machine, (D)Runner Discs, Shaft and Blades, (E) bushing and (F) Shaft Assembly

Exploded view of the complete turbine assembly and the rope and brake dynamometer is illustrated in Fig.1.



PART NO.	PART NAME	QTY.
1.	U-section	2
2.	U-section	2
3.	Flat Bar	2
4.	Angle Iron	2
5.	Angle Iron	2
6.	Handle	1
7.	Nozzle top curve cover	1
8.	Flange	1
9.	Nozzle right side cover	1
10.	Nozzle left side cover	1
11.	Back plate	1
12.	Main shaft	1
13.	Pulley	1
14.	Turbine circular cover	2
15.	Flow control holder	2
16.	Flow adjustable handle	1
17.	Flow adjustable holder	1
18.	Flow adjuster	1
19.	Flow control	1
20.	Transition pipe	1
21.	Bearing support	2
22.	Bearing	2
23.	Blade	26

Fig.1. Exploded View of the Crossflow Micro-Hydro Turbine

The equipment deployed in the construction and testing of the crossflow turbine are presented in Table 1.

Table1: Equipment for testing of the crossflow turbine

S/N	EQUIPMENT	MODEL
1.	10HP Centrifugal Pump	Harland-D215mm-SN-B4
2.	Portable Centrifugal Pump	Porte WP-30X
3.	Portable Centrifugal Pump	CITEX
4.	Portable Centrifugal Pump	CITEX
5.	Digital Tachometer	LT-DT-22358
6.	Pull-down Scale	Golden Lark-200kg
7.	Pull-down Scale	Hana-100kg
8.	Differential Pressure Gauge	Orange Incorporation USA (0-25psi)
9.	Static Pressure Gauge	DIN (-1.5 to 1.5 bar)

The test rig comprised of a 10hp centrifugal pump connected in parallel to three portable centrifugal pumps that are connected in series as shown in Plate 2.

Plate 2. Crossflow Micro-Hydropower Turbine Test Rig

A. Test Procedure

Water was pumped from the sump through the 6" Pipe. The orifice plate created the necessary pressure difference which was indicated by the Differential Pressure Gauge at the required pressure indicated in plate 3. The water was allowed to flow out of the outlet to the drain before reaching the sump, which was located at the bottom of the laboratory. By sending waters open into the pool, the turbine outlet was operating at atmospheric pressure. This was repeated for various speeds (200-400 rpm) for 15mm and 25mm guide vane openings.

A: Differential Pressure Gauge B: Precision Pressure Gauge

Plate 3: Pressure Measurement Equipment

C: Drawdown Scales D: Digital Tachometer

Plate 4: Test Rig Instrumentation Equipment

Since the flow rate depends on the pipe diameter, density and diameter ratio which are all constant at one hand and the pressure values at upstream and downstream as variables, a program was developed in excel in which torque, speed, upstream and downstream pressure of the orifice meter, and turbine inlet were manually logged in each round of test. The program gives out calculated values for power from the turbine, available hydraulic power, efficiency of the turbine, reduced speed and reduced flow.

III. RESULTS AND DISCUSSION

Figs. 2 and 3 show the experimental and numerically predicted values of the turbine for different speeds. The nature of the curves shows similar pattern for both experimental and numerical cases, the maximum efficiency value was obtained around 250 rpm at hydraulic head of 2.7m for 15mm gate opening. The maximum efficiency value was obtained around 150 rpm at hydraulic head of 2.3m for 25mm gate opening. At 254.4 rpm the numerical efficiency was 67.7% whereas the experimental efficiency obtained was 66.2% which means they are in close agreement with each other. At the 25mm gate opening and 2.3m head, the numerical efficiency was 63.7% and the experimental one was 57.6% check this. The consistency between the numerical efficiency and experimental efficiency is relatively good in terms of the nature of the curve. However, numerical efficiency gives higher values in most cases. Name two or one of them if available made similar observations. Some of the explanation for this behavior isthat, frictional efficiency and other loses are not considered in the numerical calculations.

Other reason that may bring about the observed discrepancies between the Numerical and experimental values is the numerical approach, homogeneous free surface model without buoyancy. This means that the segregation between phases due to the gravitational action on the flow could not have been taken into account. Other causes may concern numerical procedure, mesh refinement dependency, turbulence model, boundary conditions, data processing, and geometric fidelity of the turbine (Acharya *et al.*, 2015).

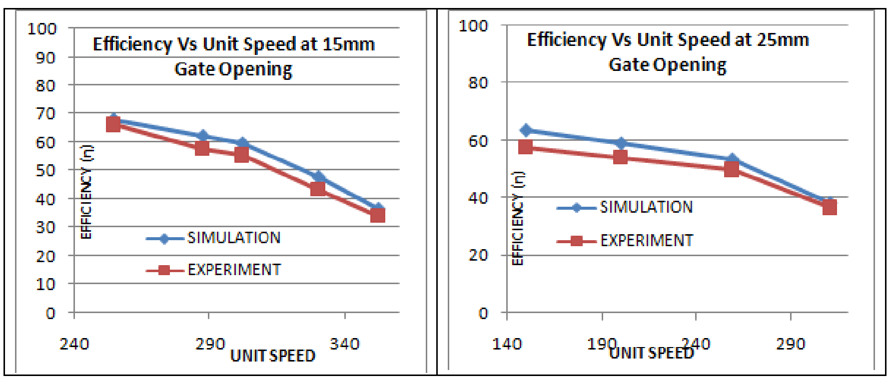


Fig.2. Plot of Efficiency Against Unit Speed at 15mm and 25mm Guide Vane Openings

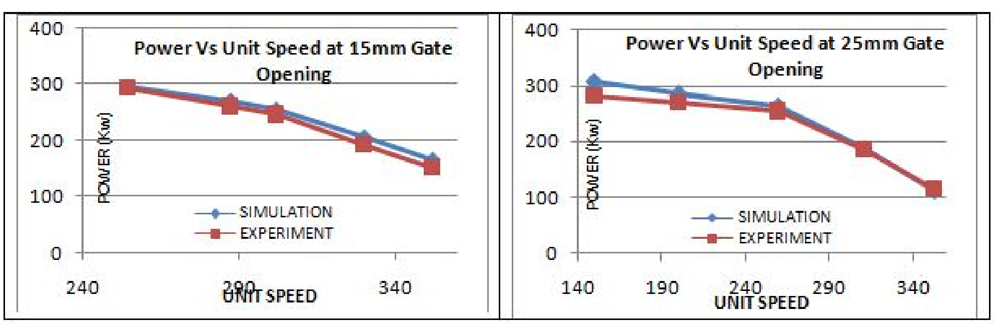


Fig.3. Plot of Power Against Unit Speed at 15mm and 25mm Guide Vane Openings

IV. CONCLUSION

The research established that a simplified turbine that can be manufactured with locally available materials and in a local workshop with already available technology can be competitive with sophisticated turbines like Kaplan turbine in terms of efficiency and application. An efficiency of 90% at design flow rate and efficiency of 70% at 22%-part flow and 40% below design head were achieved.

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