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Application of the Pelton Wheel for local low level Electricity Generation

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Abstract— The Pelton wheel is a device which converts kinetic energy of moving water to rotary energy which can be used to generate electricity through electromagnetic induction. It's unique as it does not require heavy moving water before it works. It earnestly makes use of impulse of water jet based on the shape of the cups which does not allow any obstruction in water movement during operation. The availability of energy is of great concern in any manufacturing industry and other small scale entrepreneur in Nigeria. Generation of electricity for local area remains a challenge in power industry. Hence, This paper presents the design, construction and testing of an locally made Pelton Wheel for converting Kinetic Energy of falling water to Electrical Energy. The experimentation was carried out at Ladoke Akintola University of Technology (LAUTECH). The designed component was divided into four; the upper unit, the casing, the base unit and miscellaneous parts. An height of 8.23m with a water tank of 1000litres (1m^3) and 12 Volts alternator were used for the experimentation. The output of the turbine was used to lit a 5W bulb and there could have been a better output, if a waterfall was used as a source of water to power the turbine. The constructed turbine could be use as instructional material in training mechanical engineering students.

Keywords— pelton wheel; low level; electricity; generation

I. INTRODUCTION

"A Pelton wheel is a free jet water turbine, with cups also called buckets, of elliptical shape attached to the rotating wheel, which extracts energy from the momentum of moving water, as the impulse of the water causes the rotation of the wheel" [1]. It is called water turbine, since the fluid involved in its operation is water. As a prime mover, it converts the kinetic energy of flowing water to mechanical energy, as a result of the pressure due to a head of water in a reservoir above the turbine, being converted to kinetic energy. This wheel was named after Lester Allen Pelton [1].

Pelton wheels are of different sizes, depending on the volume of water, available head and the amount of electricity to be generated. Among the parameters that affect the power developed is the flow rate of the fluid involved, which flows through the nozzle[1]. The amount of power generated can be maintained with less volume of water flow, by increasing the height of water fall (head). It gains a greater amount of kinetic energy from a jet of water, than a conventional water wheel [3]. This can be achieved by turning the water jet through an angle closer to 180^o, which nearly doubles the rate of momentum and hence the force exerted by the fluid (water).

Among the applications of water wheels are; to power machines like mills, and to generate electricity both in larger and smaller quantity. One of them is the production of micro-turbines, which generate electricity for running household appliances, using small rivers, or water stored in a large reservoir. "Water turbines are clean power producer" [6], as they cause no significant changes to the water, but alter the natural ecology of rivers potentially killing aquatic animals and disrupting water transportations. They use a renewable energy source, and are designed to operate for decades.

The optimum use of energy is of great concern in any manufacturing industry and other small scale entrepreneur in Nigeria. Generation of electricity for local area remains a challenge in power industry. However, in order to optimize the distribution of electricity to local areas and to reduce the difficulties involved in local generation of electricity, this paper present the development of a turbine for power generation in local areas and small scale industries.

The Pelton wheel designed was for low level electricity generation; mainly designed to earnestly make use of the waste energy for household and other small industrial purposes, using nearby waterfalls. Also to serve as instructional material for Fluid Mechanics students and at large provides solution to the power problems of small-scale entrepreneurs and artisans for better economic development of the communities.

This work is limited to the design, construction and testing of a local Pelton wheel for low level electricity generation, of about 5W with 7.30m water head, using a wheel of diameter 600mm with 8 attached Cups.

II. LITERATURE REVIEW

A. *History of Pelton's invention*

Pelton's invention started from an observation made sometime in the 1870s [4]. He observed the slippage of the key holding the turbine wheel unto its shaft, when watching a spinning water turbine. This caused the shaft to become misaligned. The slippage made the jet to hit the cups near the edge, making the flowing water to be deflected into a half circle, and coming out again with reverse direction rather than the water flow being stopped. Surprisingly, the turbine speed now increased. This was Pelton's great discovery. In the existing water turbines, the jet hit the cups at the middle, causing the splash of the impacting water, which resulted in a level of wasted energy[1][9]. Pelton then decided to design his own turbine wheel, in order to reduce the wasted energy, and increase the speed of rotation of the wheel for maximum efficiency by using double cup, with a wedged shape divider in the middle, splitting the jet into two equal half, one to the left and the other to the right. This was arranged in such a way that the jet of water was directed to the splitter, which enhanced the reverse of the flowing water [9]. He finally obtained the patent for his invention in 1880.A design competition that was held in 1883 showed that Pelton's turbine is 90.2% efficient, and the turbine of his closest competitor is only 76.5% efficient. This made it to win the competition for the most efficient water wheels. After this, mass production of his turbine started in 1888 in his newly formed Pelton Water Wheel Company in San Francisco [4].

III. METHOD AND MATERIALS

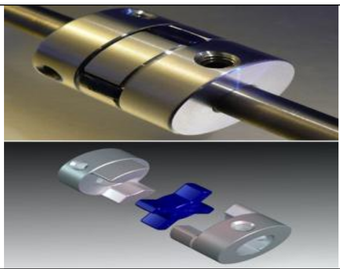
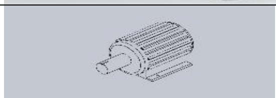
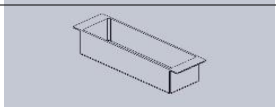
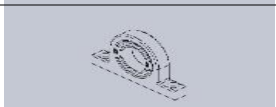
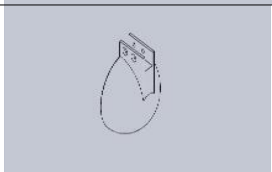
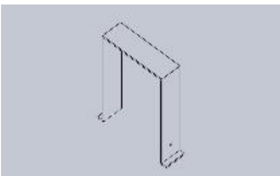
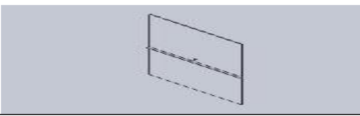
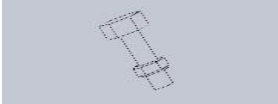
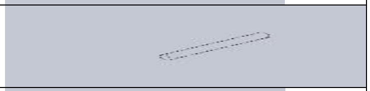
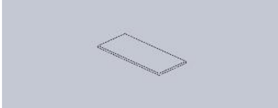
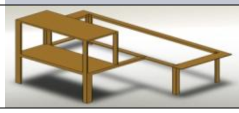
The basic machine components can be divided into four; the upper unit, the casing, the base unit and miscellaneous parts. **The Upper unit** contains the turbine wheel, shaft, cups, bolts, nuts, coupling, bearings, and the generator. The **Turbine Wheel** is a circular disc of diameter 600mm and thickness 70mm with the cups in position being integral with the wheel. The cups are to receive impact loading due to water jet. The impact of the water jets on the wheel causes the wheel to rotate. This part was carved from *Gmelina arborea* wood species. The wood was selected as a constructional material in order to limit weight and thus increase speed at a given torque. It was also preferred to aluminum because of its better fatigue resistance than aluminum. The wood was painted using high quality linseed oil paint to make the wood impervious to water. It is also to avoid the wood being rendered weak and susceptible to biodeterioration. The cups were made symmetrically to combine two cups and a splitter, inculcated in a single cast, with a smooth surface to avoid frictional losses during the operation. It was designed with an elliptical shape of major axis 150mm diameter, minor axis 100mm diameter and of depth radius 40mm with two handles, to adequately fit on the wheel. This prevents the cups from shaking, which may result from impact loading imposed by water jet when hitting the cups. This part was made from cast aluminum, to ensure high corrosion resistance and light weight. The H**ollow Shaft** is a metal that transmitted the rotational motion of the wheel to the generator. It was made of mild steel, in order to reduce the weight of the machine, limit bending and twisting during rotation. The shaft of 55mm outer diameter and 30mm inner diameter and of length 500mm was stepped turned to hold the bearings, and was coupled with generator to ensure maximum torque transfer in-between the shaft. **The Coupling** was made from cast iron and abrasive rubber. The rubber was inserted in between the metals to reduce the heat generated as a result of friction between metals in contact. **The pillow bearings** are ready made standard bearing made from ferrous material, with specification P209. Each bearing was attached to the side of the casing to support the shaft. This provides relative positioning and enhances free movement, to avoid whirling of the shaft while transmitting load between two parts. Pillow bearing was selected to avoid being in contact with water by keeping a little gap away from cover plate. A 12volt generator was selected for this design based on the available water head the turbines was intended to work with as it determines the power to be generated by the turbine. The casing was the cover, frame, smooth bore nozzle and slide cover coated with aluminum paint and supported with bearings to protect the rotary parts of the turbine. The **Cover is made from a** mild steel plate of 450x3300mm, 1.2mm thick folded to form the required shape to shield the movable parts, to hold the nozzle in proper position and to avoid the splash of water during the operation. The dimension was also made guide against excessive vibration and to reduce the weight of the machine when bolted to the frame. The side cover is a mild steel plate of 1100mm^2 designed to be braced with angle iron at the middle. The angle iron served as sit for bearing which hold the shaft. This protects the splash of water during the operation and limits the risk of being exposed to electric shock by shielding the movable parts. The **Frame** was designed to hold the generator, position the shaft and to strengthen the casing. The frame was not only subjected to vibratory load but also carried the weight of the coupled wheel. It was made from 50mm by 50mm angle iron with thickness 2mm. the w**ater Basin is a 50litres container made of mild steel** designed to control used water (water passing out of the wheel during operation) in order to avoid watery floor which could be dangerous to the purpose for which the machine was designed. The sketches of different part are shown in the Bill of Material and Component Table 1 and Table 2 has material and their sketches.

TABLE I. BILL OF MATERIALS AND COMPONENTS

Part Name	*Material*	*Quantity*	*Specification*	*Dimension*
Coupling	Cast iron and Abrasive rubber	1	Standard product	Purchased whole
alternator		1	15v	purchased
Water basin	Mild Steel Plate	1	1.2mm mild steel plate	purchased
Bearing	Cast steal	2	P209	purchased
Cups	Cast aluminum	8	Cast aluminum	An elliptical cup with major diameter 150mm and minor diameter 100mm
Turbine wheel	Gmelina arborea Wood	1	600mm diameter wood material	70mm thickness
Upper Frame Cover	Mild steel plate		1.2mm mild steel plate	2000mm by 300mm
Side cover	Mild steel plate	2	1.2mm mild steel plate	1000mm by 800mm
Bolt and nuts	Mild steal	4 and 2 respectively	10mm in diameter and 12mm in diameter respectively	Purchased

Part Name	*Material*	*Quantity*	*Specification*	*Dimension*
Shaft	Mild steal	1	50mm mild steel rod step turned at the edge.	600mm lenght
Tablet plates	Mild steel plates	2	2mm mild steel plate	600mm x 800mm
Frame lenght	Mild steal	2	50mm x 4mm angle iron	1000mm lenght
Frame stand	Mild steel	4	50mm x 4mm angle iron	1400mm lenght

TABLE II. PART AND SKETCHES

Part Name	*Sketch of component*
Coupling	
alternator	
Water basin	
Bearing	
Cups	
Turbine wheel	
Upper Frame Cover	
Side cover	
Bolt and nuts	
Shaft	
Tablet plates	
Frame length and legs	

A. *Fabrication Procedure*

Fabrication procedures include:

1) Turbine Frame Fabrication Procedure: To fabricate the frame stand (leg) 50mm by 50mm angle iron with thickness 2mm was cut to the required length of 1500mm into 4 pieces. For cross member, another angle iron of the same dimension was cut into 1100mm to produce the length of the frame and 350mm to produce the breadth, all of 4 pieces each. The parts were welded together using arc-welding to form the frame.

2) Turbine Wheel Fabrication Procedure: The thickness 50mm with diameter 600mm which was marked from the Gmelina arborea wood specie with the help of scriber after the centre point has been located. With radius 300mm, a circle was marked out and the remaining materials were chipped out and machined to have a smooth surface and the required dimension. This was bored at the centre with boring tool to make a hole of 50mm which hold the shaft. The other portion to remove was marked out and chipped out to form the required shapes which also reduce the weight of the wheel. The carved pulley was painted with aluminum paint.

3) Turbine Shaft Fabrication Procedure: A mild steel hollow shaft of 55mm outside diameter and 30mm inner diameter with 500mm length was turned on lathe machine to reduce its diameter to the required diameter of 50mm. The shaft was further stepped turn at the two ends to accommodate the bearings.

4) Turbine Cups Fabrication Procedure: An elliptical cup of major axis 150 mm diameters and minor axis 100mm diameter was carved with wood, inculcating a splitter at the middle in a longitudinal axis. This was used as a pattern to produce mould for cast. The molten aluminum was gotten by melting aluminum scrap which was used to produce the cups.

5) Frame Cover Fabrication Procedure: These components were produced from 1.2mm mild steel plate which was cut into the required length of 3300mm by 450mm and was folded by 50mm at each side to produce the desired shape.

Side Cover and Bearing support Procedure: These parts were produced from 1.2mm mild steel plate which was cut to the desired dimension of 1100mm by 1100mm. These plates were marked diagonally to locate the centre, and was centre point using centre punch. A circle of radius 25mm was marked and chiseled out for passage of the shaft and the circle was smoothened using manual round file.

B. Assembly of the Experimental Water Turbine

The assemblage of the machine commenced with the building of the frame. Fig. 1 shows the exploded view of the experimental turbine machine. The cover was joined by welding the frame cover to the frame and the two side covers were fixed to the frame by using bolt after the frame as been tapped to serve as nut for the bolt., Both the frame cover and side covers were set and talked to the frame using arc-welding before it was drilled and tapped which allow the bolt to hold the plate to the frame for easy removal in case of repair of turbine components. The two side covers were removed, to be able to gum the rubber round the frame, the rubber prevents water leakage through the wall of the experimental turbine during operation. One of the side cover was then fixed and braced with bearing sit, after which the bearing was mounted. The turbine cup assembly coupled with shaft was fixed after the other cover was fixed with its bearing sit. The shaft of the coupled wheel was then connected to the shaft from the larger gear system inculcated in-between the shaft and the alternator, the shaft from the smaller gear were also connected to the alternator shaft using coupling.

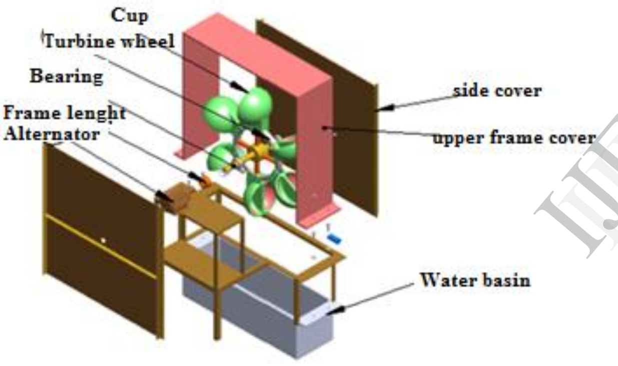


Fig. 1. Exploded view of fabricated turbine

IV. FABRICATION TESTING

The experimental water turbine was tested with all the appliances and set up shown in fig. 2. The water tank was filled by pumping water from a water container set on the ground, the water from the tank was allow to run through the channels to evacuate the channel vacuum. The head of water was measured from the open end of water tank as the water surface is the point at which the gravity directly affects the water and therefore the starting elevation of the system and the turbine elevation end at the water exit of the turbine nozzle where the water exits the closed diversion system. The power generated was determined by the height of waterfalls and the impact of water jet on the cups, which dictates the speed at which the wheel rotates. The height used for this experiment was 8.23m with a water tank of 1000litres ($1m^3$) which also influenced the alternator used (12volt alternator).

Fig. 2. picture showing the full set of the experimental turbine.

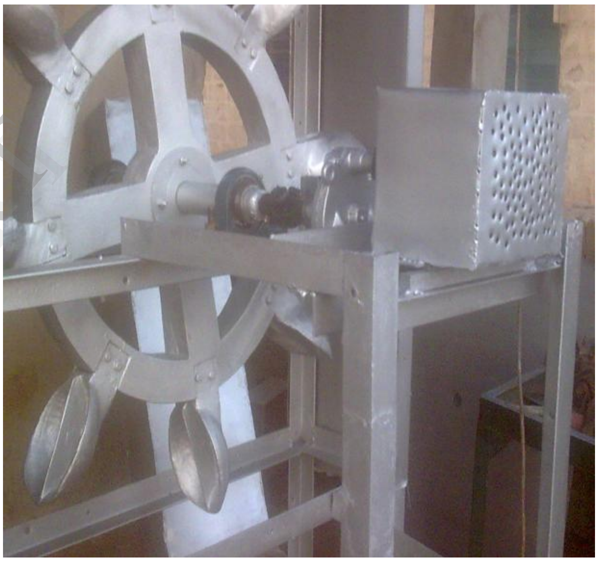


Fig. 3. picture showing the inner part of the fabricated turbine

The readings were taken with the two terminals connected and the voltmeter set to 0.00 and the measurements were taken at different time based on the changes observed in the speed of the coupled wheel which gives the variation in the result. The result obtained is shown in Table 3.

TABLE III. OUTPUT VOLTAGE OF AT DIFFERENT TESTING HEIGHTS

Trials	***Height of waterfall (m)***	***Voltmeter Reading (Volts)***
First Trial	7.00	4.95
Second Trial	7.30	5.10

V. Conclusion

The Pelton Wheel was designed and successfully used to generate electricity. It was also a useful aid in the Fluid Mechanics Laboratory as it used as instructional material in teaching students. The output of the turbine was used to lit a 5W bulb and there could have been a better output, if a waterfall was used as a source of water to power the turbine. Hence, it was concluded that Pelton wheel water turbine is a unique water turbine as it does not require very large stream of water for its operation which makes it a good experimental machine. It is therefore recommended that a larger capacity of this turbine can also be built by communities with waterfalls to solve rural electrification problems when approved by Power controlling body, e.g. Power Holding Company of Nigeria.

References

[1] W.F. Durrand, The Pelton Water Wheel, Stanford University, Mechanical Engineering, 1939.

[2] K. Donners, M.Waelkens and J.Deckers, "Water Mills in the Area of Sagalassos:a Disappearing Ancient Technology", Anatolian Studies (British Institute at Ankara), 2002, pp.52:1–17.

[3] R.K. Rajput, Textbook of Hydraulic Machines. S. Chand and Company Ltd. Ram Nagar, New Delhi, 1989

[4] A. Wilson, "Water-Power in North Africa and the Development of Horizontal Water Wheel", Journal of Roman Archaeology, Vol. 8, pp. 499-510, January 1995.

[5] A. Wilson, "Machines, Power and the Ancient Economy", The Journal of Roman Studies, Vol. 92, pp. 1–32, November 2002.

[6] Wikander Orjan, Handbook of Ancient Water Technology, in Technology and Change in History 2, Leiden: Brill, 2000, pp 371 - 400.

[7] C.S. Sharma and Purohit Kamalesh, Design of Machine Elements, Prentice Hall of India, New Delhi, 2003

[8] J. Carvill, Mechanical Engineer's Data Handbook, 2nd ed., Butterworth-Heinemann Publishers, Oxford, 2009.

[9] J.E. W. A. Doble, The Tangential Water Wheel , Transactions of the AmericanInstitute of Mining Engineers, Vol. XXIX, 1899.

[10] Shigley and C.R. Mischke, Mechanical Engineering Design, 5th ed., McGraw-Hill Publication, 1989