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Design and Fabrication of Pico Hydro Turbine

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***Abstract* –This paper describes the procedure for design and fabrication of a pico-hydro turbine. Small amount of energy saved contribute towards saving the environment. The idea is to get electrical energy from water flowing in pipelines of a building from overhead tank to the taps in homes. A building of three floors is considered for the study. The water flowing in the pipe has sufficient amount of energy to rotate a pico-hydro turbine. The energy is extracted from a dc generator coupled to the rotor of the turbine. The fabrication of the turbine is done using the 3D printing technology which uses fuse deposition modelling technique.**

Key Words: Pico-hydro turbine,3D printing.

I. INTRODUCTION

Hydro Power plants:

Hydro power is a very clean source of energy and only uses the water, the water after generating electrical power, is available for other purposes. Due to this reason, hydropower plants become more and more importance. These are few types of hydropower plant which depends on the size.

A)They are classified as follows:-

1) Large Hydro: 100 MW or more of generating capacity.
2) Small Hydro: 1 to 10 MW of generating capacity.
3) Micro Hydro: 5 KW to 100 KW of generating capacity.
4) Pico Hydro: Less than 5 KW of generating capacity.

B) Classification of hydro turbines based on direction of flow:

1) Tangential or peripheral flow
2) Radial inward or outward flow
3) Mixed or diagonal flow
4) Axial flow types

C) Classification of hydro turbines based on specific speed:

1) **Low specific speed:** This employs high head in the range of 200m upto1700m. These machines require low discharge. Example: Pelton wheel. Ns = 10 to 30 single jet.
2) **Medium specific speed:** This employs moderate heads in the range of 50m to 200m. Example: Francis turbine, Ns = 60 to 400.
3) High specific speed: This employs very low head in the range of 2.5 m to 50m. These require high discharge. Example: Kaplan and propeller etc., Ns = 300 to 1000.

D) Classification of hydraulic turbines based on pressure change:

1) **Impulse Turbine**: The pressure of liquid does not change while flowing through the rotor of the machine. In Impulse Turbines pressure change occur only in the nozzle of the machine. One such example of impulse turbine is Pelton Wheel.
2) **Reaction Turbine**: The pressure of liquid changes while it flows through the rotor of the machine. The change in fluid velocity and reduction in its pressure causes a reaction on the turbine blades; this is where from the name Reaction Turbine may have been derived. Francis and Kaplan Turbines fall in the category of Reaction Turbines.

II. PROBLEM STATEMENT

1) The problem is the inaccessibility of electricity in remote areas and well as the high energy consumption of power in commercial and residential areas.
2) Water flowing through commercial and residential buildings has sufficient potential energy to generate power, which is being wasted flowing through pipes.

III. OBJECTIVES

1) This project aims on design and fabrication of a Pico hydro turbine for extraction of electrical energy from the water flowing in the pipelines from the overhead tanks.
2) The investment and installation of Pico Hydro Turbine is more cost effective than solar or wind

energy generation plants when energy per capital is considered.

IV. METHODOLOGY

It refers to a process by which digital 3D design data is used to build up a component in layers by depositing material. The term "3D printing" is increasingly used as a synonym for Additive Manufacturing. A range of different metals, plastics and composite materials may be used. Subtractive manufacturing is a process by which 3D objects are constructed by successively cutting material away from a solid block of material. 3D printed parts can be made using FDM (Fused Deposition Modelling) printers. FDM works on an "additive" principle by laying down heated plastic filament material in layers. Within FDM printers, machines could utilize ABS (Acrylonitrile Butadiene Styrene) or PLA (Poly lactic Acid) as the polymer material. Initially the CAD model is fed to the machine with a memory card. Based on the shape of the component the support structure is created(ref fig.1.2). The process begins by heating the material reels called and converting it into molten state. Then with the help of extruder the fused material is directed towards the print bed. Initially the base structure or support structure is created and then the component is 3D printed. The key components involved in a 3D printer are print bed, print display and hot end nozzle, filament reel, cooling fan, extruder and card reader.

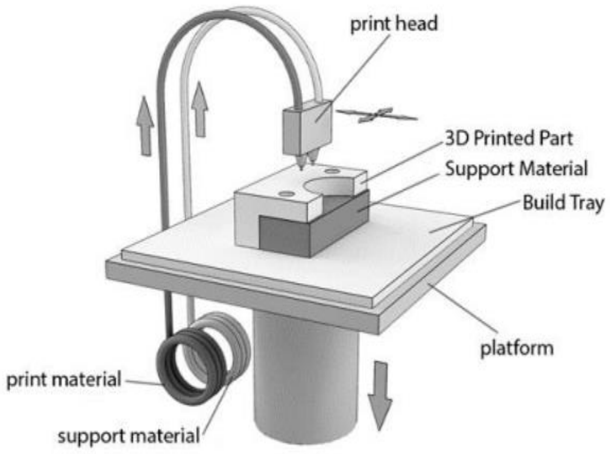


Fig.1.2 FDM principle [2]

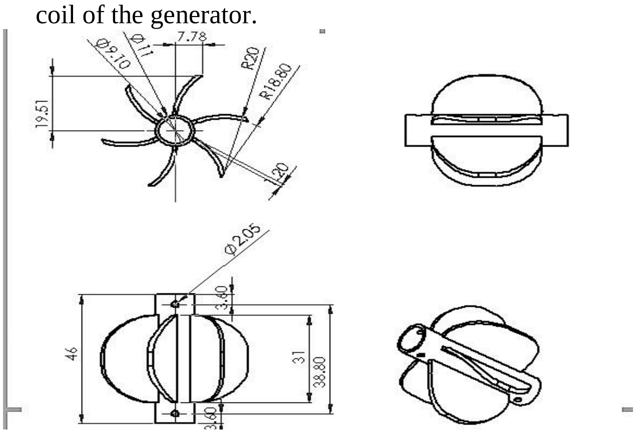
V. CONSTRUCTION AND WORKING OF PICO HYDRO TURBINE:

A. Components:

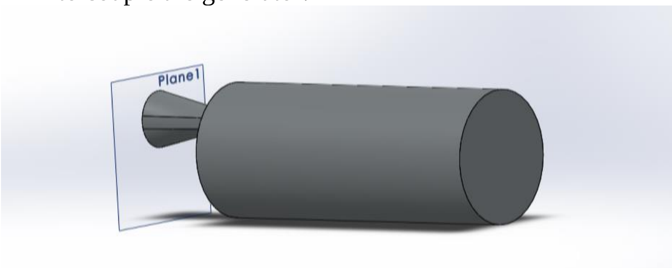
A) Nozzle: Here the kinetic head increases with decrease in cross section.

B) Rotor:

This is an impulse type of hydraulic turbine. The rotating component has bladeson the circumference of the hub. The energy from the water is extracted by dynamicaction of rotor, resulting in change in momentum and pressure of fluid which results inthe rotation of the blades. The hub is the hollow circular shaft having blades on itscircumference. The hub coupled to main shaft which rotates the armature coil of the generator.



C) Casing: The casing houses the nozzle and rotor assembly. It guides the water to outlet. It also provides the supporting structure for the bearing and to couple the generator.



D) Generator: The 12V 600 rpm DC generator is couple with the main shaft of the rotor. Here the mechanical energy of the rotor is converted into electrical energy. An external energy storage unit (battery) can be used to store energy produced.

E) Bearing: Bearing will be added to hold the turbine and the supporting the main shaft. So the design of turbine will be able to freely rotate.

5.1 WORKING

Water in the overhead tank has sufficient amount of head (energy) to extract electric energy on small scale. Hence a pico turbine can be installed in a pipeline where water flows from overhead tank to taps at home when the water flows through the pipe it flows through the nozzle and hits rotor this makes rotor and shaft to rotate and inturn DC generator which generates electricity and can be stored in battries.To get expected power output more number of turbines can be installed and connected to battery.

VI. MATERIAL SELECTION:

ABS– ABS or Acrylonitrile butadiene styrene is a common thermoplastic polymer typically used for injection molding applications. This engineering plastic is popular due to its low production cost and the ease with which the material is machined by plastic manufacturers. Better yet, its natural benefits of affordability and machinability do not hinder the ABS material's desired properties like : Impact Resistance, Structural Strength and Stiffness, Chemical Resistance, Excellent High and Low Temperature Performance, Great Electrical Insulation Properties, Easy to Paint and Glue.

FDM machine uses ABS plastic which allows us to be certain that there will be no major hold-ups due to material when transitioning from prototype to production. It is often chosen because it is a good middle-ground option for a huge number of applications. ABS is easily machined, sanded, glued and painted. This makes it a great material for prototyping. You can also get good cosmetic finishes with ABS and it can also be colored relatively easily, unlike some other plastics. This is a reason it is often used for enclosures (housing) that might have different textures or glossy surfaces.

Material Properties of ABS

Material Property	ABS
Density (kg/m3)	1.01 – 1.21
Young's Modulus (GPa)	1.10 – 2.9
Yield stress (MPa)	18.5 – 51
Tensile stress (MPa)	25 – 50
Ultimate Tensile strength (MPa)	33 – 110
Fracture toughness (Mpa/m)	1.19 – 4.3
Strength to weight ratio (kNm/Kg)	31 – 80
Impact strength Izod (J/m)	317.5
Flexural strength (MPa)	48.2

VII. ANALYSIS OF ROTOR

STATIC ANALYSIS:

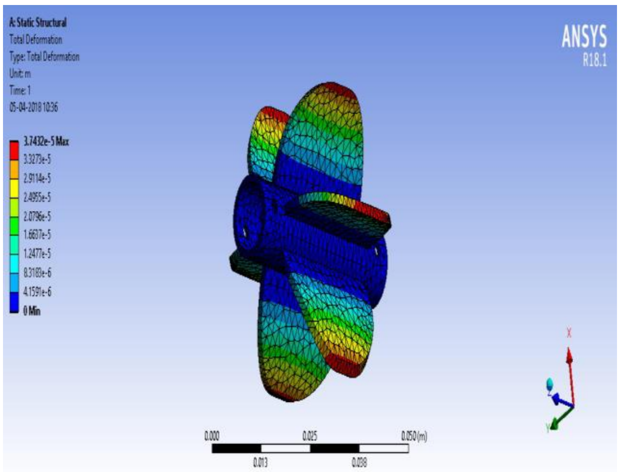


Fig. Total deformation

This image of static analysis shows the deformation of blades of rotor due to force applied by impinging water. We observe that more is the deformation in the outer end as the inner end is fixed to the hub. There is no deformation of the hub.

VIII. CALCULATIONS

*In hydroelectric projects, calculations are based on the available hydraulic head. This is a measurement of the difference in elevation between the water source and the turbine.

Tank capacity 2000litres

Height of building 25feet

Average residential water pressure 25psi to 75psi. Consider 25psi.

1psi = 6.89kpa

25psi = 172.35kpa

*Hydraulic head $H=P\rho g$ = (173.25 * 1000)/(9810) = 17.56m.

P= Average residential water pressure.

ρ=Density of Water

g=Acceleration due to gravity

Time taken for filling volume of 20litre is 80secs.

*Volume flow rate Q = V/t = (20*10-3)/80 = 2.5*10-4 m3/s

V= velocity of water.

t = time taken

Hydraulic power:

P = ρgHQ = 9810*17.56*2.5*10-4=43.06w

Q = Volume flow rate in m3/sec

H = Hydraulic head

* Jet velocity Vj = Cv(2gH)0.5

Vj = 0.96*(2*9.81*17.56)0.5 = 17.019 m/s

Cv= Cofficient of discharge.

Cv varies between 0.96 to .98

* Velocity ratio = u/Vj = 0.46

u= Blade speed.

Then tangential blade speed u = 8.018 m/s

*Turbine efficiency ή = 4u (Vj-u)/Vj2 = 0.91

*Pout = ή*P

*Pout= 0.91*43.06 = 39.1w

Pout= output power

*Power generated Pg = ηg*Pout =31.28 watts

Assuming ηg = generator efficiency to be 0.8.

IX. RESULTS AND DISCUSSIONS:

Experimental Output taken at different heights:

Sl no.	Building	Height (feet)	Voltage (volts)	Power (watts)
1	1	13	4.23	3.384
2	1	26	5.73	4.590
3	2	13	4.34	3.472
4	2	26	6.02	4.820
5	1	39	11.51	10.474
6	2	39	12.01	11.649

The readings were taken down at two different buildings.The current output depends of loading condition. It ranges from 0.6 to 1.2amps.

X. CONCLUSION:

The project was to design and develop a small size turbine concept to utilize and generate electricity using water stored in the overhead tanks of a residential building. This also deals with alternative manufacturing process using 3D printing which utilizes FDM technique. An optimization methodology is developed for the design and the development of Pico hydro turbine runner blade using 3D Solid Works modelling. The calculations were made as per the generation of approximately 12W power using water from an overhead tank.

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