Energy Generation Using Portable Water Turbine

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Abstract: The hydro turbine harnesses kinetic energy in the form of flowing water and converts it to electrical energy by means of a turbine and generator. Compared to solar energy, hydroelectric power has significantly larger energy density. Our visions with the hydro turbine was to take the concept of this energy converting mechanism and size it down to a portable, compact device that can be carried by hand, stored in a backpack, and easily transported for charging anything from a cell phone to a laptop, anywhere. In remote places due to frequent power cuts the alternate source of energy for house hold power requirements is very essential. Also, it is necessary that this source should be portable and easily operated by common man. . The goal of this project is to design and build a micro-hydro electric power system for use in rural parts of India which do not currently have power, but do have access to streams and small waterfalls. This paper focuses on the design, integration, and construction of a system that harnesses energy from flowing water. . The generator could not output the specified power. Details of the design along with ideas for further improvement are presented in this report.

keyword- Portable, Rotating Blade, 3D printing, hydropower, energy conversion.

INTRODUCTION

Hydroelectric power is produced when water turns a turbine connected to a generator. This water is stored behind a dam at elevation. Gravity causes water to drop toward a turbine propeller. The falling water turns the turbine which produces power through the connected generator. Hydroelectric power, or hydroelectricity, is basically electrical energy that has been generated using natural forces such as gravity or flowing water. It's usually produced by dams, because dams can store and direct large volumes of water. But it is too costly. The purpose of this project is to design and fabricate low head water turbine which should be economical. Micro-hydro refers to projects that generate between 0.5 kW and 100 kW of power, which is the amount of power typically required by a single family home or a small business. Small hydrokinetic systems fall within this micro-hydro category and offer portability.The design of the portable hydro turbine takes into consideration many specifications and constraints that are ideal for a great product.

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LITERATURE SURVEY

Damodhar R,Mruthyunjaya K N,Naveen, K Pavan Prabhakar, Rakhesh H S [1]In this paper a water turbine is designed and fabricated based on the ideals of Tesla's turbine. The main aim of this turbine is to utilize the kinetic energy and potential energy of conventional water supply.Tesla's turbine is a bladeless turbine which uses series of rotating discs to covert fluid flow energy into mechanical energy .The reason for selecting this turbine is its simplicity in the design and concept. The purpose of this project is to design and fabricate low head water turbine based on Tesla's turbine design. Based on Tesla's model modifications are planned to the design to improve the efficiency. The modifications planned so that the turbine is made suitable for low head applications.The turbine can be used in remote locations where there is shortage or no supply of electricity. Since it is portable it can be carried easily and used where a source of water is available to generate power.

W.C. Schleicher, J.D. Riglin, A. Oztekin[2]In this paper various blade designs are characterized and compared in terms of torque and thrust over a range of operating conditions.Micro-hydro refers to projects that generate between 0.5 kW and 100 kW of power, which is the amount of power typically required by a single family home or a small business. Small hydrokinetic systems fall within this micro-hydro category and offer portability.Various blade designs are characterized and compared in terms of torque and thrust over a range of operating conditions.The portable hydrokinetic turbines, designed and characterized here, do not require large civil structures, making this technology an attractive alternative to conventional hydropower.

Avtar S. Khalsa[3]The main aim of this research paper is to build a micro-hydro electric power system for use in rural parts of India which do not have access to streams and small waterfalls. According to the most recent Indian census, there are 593,732 total villages in India, of which 488,173 have power. This means a whopping 17.8% of villages in India do not have power. When one further considers that more than two thirds of India's enormous population lives in these small villages, it becomes clear that this is a problem that affects millions of people. The need for an inexpensive source of power in India is very significant

CONCEPTUAL DESIGN

Below is a concept of what we expect our portable hydro turbine to look like and we have also started some conceptual sketches of how the mechanism will function.

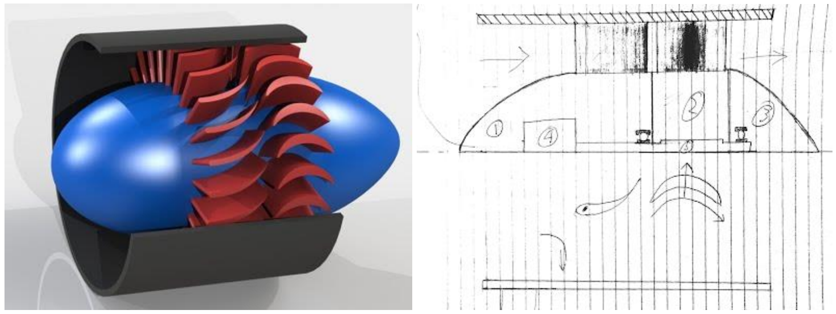


Figure:Conceptual deaign

1. Housing for generator
2. Moving turbine blade
3. Shaft support (bearings)
4. DC generator
5. Shaft

DESIGN CONSIDERATIONS

- Portability
  - Maximum envelope of 15x15x20 cm3
  - Lightweight
- Economical
  - More affordable than current solar technology (under $100)
- Waterproof
  - Water-tight enclosures housing electronic components
- High Power Output
  - 30-40 Watts
- Robust
  - Durable and wear-resistant materials and construction
  - Blades capable of withstanding maximum expected loads
- User-Friendly
  - Quick and easy to set up

CALCULATIONS

Theoretical power that can be generated by a hydroturbine can be calculated as below:

$$P = \eta \rho Q g h$$

Where,

- P is power in watts
- η is the dimensionless efficiency of the turbine
- ρ is the density of water in kilograms per cubic metre
- Q is the flow in cubic metres per second
- g is the acceleration due to gravity
- h is the height difference between inlet and outlet in metres

To maximize power, we seek to design an efficient hydroturbine that can take advantage of waterflow in various environments, e.g. in a stream or creek. Ideally, the design should allow the turbine to be adaptable to these various environments as well as different depths. Additionally, the material choice for the enclosure as well as the the turbine is critical for properly balancing factors such as strength/rigidity, weight, and resisitance to corrosion.

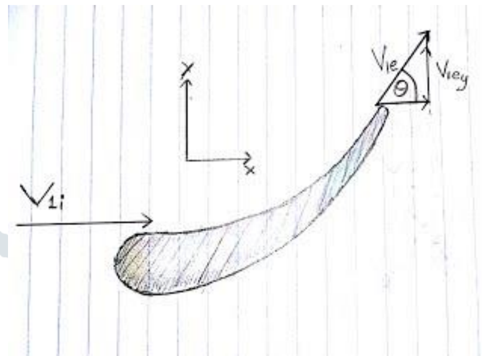
In fluid mechanics the momentum equation tells us that whenever we redirect thepath of a fluid, there must be a force acting between the fluid and its surroundings.In the case of a hydro turbine, we redirect the water using the turbine bladesand use the force that is created to spin a generator and create power

$$\sum F_x = \dot{m}(V_{x2} - V_{x1})$$

In its most simple, 1 dimensional form, the fluid momentum equation tells us that the component of this force in any direction is simply the mass flow rate multiplied by the change in fluid velocity in that direction.Our turbine uses a two stage blade system; the first stage of blades - which are fixed in place - force the water into a swirling motion which then flows through the second blade stage. The second stage redirects the flow in the opposite direction and the force created by this path change rotates the stage and drives the generator.This two stage design allows us to redirect the water mire than in a single stage design and thus harvest more energy from the water.

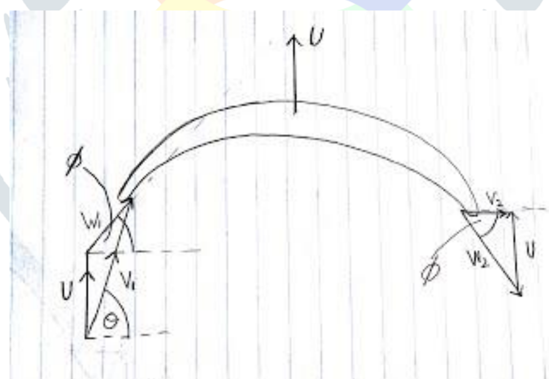
In this simple analysis we will imagine that all of our fluid flows through a single pair of blades, these pictures are drawn on an XY coordinate system but in our turbine these are the axial and radial directions respectively.

Stage 1:



As the above image shows, the first blade simply rotates the velocity vector of thewater by an angle theta, this angle is determined by the blade geometry and controls how we design the second blade and how much energy we can harvest. We canuse the momentum equation here to calculate the load on the blade which we can then use for structural analysis, but since we are currently focused on generating power we will ignore this.

Stage 2:



This diagram is a bit more complicated, these complications are caused by the blade velocity U. The blade velocity means that the velocity of the fluid relative to theblade is different. In our analysis of this blade we're going to assume that relative to the blade, the water simply flows along the blade and off the other end as it did in stage 1. The force acting on the blade can then be calculated using the equation at the top of the page but this time in the y direction. Using some basic trigonometric relations this can be written as:

$$F_y = 2\dot{m}(V_1 \sin\theta - U)$$

To calculate the power dissipated in the blade we simply multiply this by the blade speed U, from this we can establish that the most power is drawn from the fluid when:

$$U = \frac{1}{2} V_1 \sin\theta$$

When this condition is satisfied, the water has no y velocity component and so istraveling in the exact same direction as when it entered the turbine. If we want todesign our blade geometry for this condition then:

$$\phi = \tan^{-1}(\frac{1}{2}\tan\theta)$$

PORTABLE WATER TURBINE COMPONENTS

Turbine consists of following main components

No.	Part	Quantity
1.	Outer Body	1
2.	Nose Cone Half	2
3.	Stationary Blades	2
4.	Rotating Blades	1
5.	Rear Support	1
6.	Motor	1
7.	Sealed Bearing	2
8.	M3 Screws	10
9.	Threaded Inserts	10
10.	Handle	1
11.	Gaskets	1
12.	Oring	1
13.	Axle Lip Seal	1

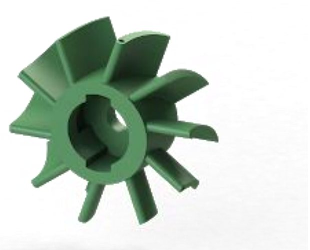
Outer Body:

The outer body is a polypropylene tube which has been machined to have 7 holes in order to screw the body to 4 of the stationary blades as well as to the three pillars of the Rear support. 2 more holes need to be drilled in order to screw the handle to the outer body. Therefore 9 M3 screws as well as 9 threaded inserts are needed for this part. The purpose of the outer body is to keep our turbine together and protect the blades from collisions which might occur while carrying the portable hydro turbine. The bigger holes seen at the front of the Outer Body have been designed in order to allow fixing of the portable hydro turbine in a stream using a stick which can be found on location or using strings to attach it to both sides of the river.

Nose Cone Half:

The purpose of the Nose cone is to house the motor and make sure it does not get wet. It is built in two parts which are screwed together using an M3 screw and a thread insert. In order to remain sealed, it is designed to contain an oring at the intersection between the nose cone and the stationary blades.

Stationary Blades:



The set of stationary blades is one of the most crucial components of our turbine along with the rotary blades. Its purpose is to redirect the flow of water in order to maximize the power produced by the second set of blades. Indeed, as the flow is redirected, it is almost perpendicular to the second set of blades as it arrives at that stage and therefore the change of momentum produced by the rotary blades on the water is greater, producing more power. Also, the role of these blades is to keep the components together as it is attached to the outer body by 4 M3 screws.

Rotary Blades:

This is the part of our turbine which produces power as it changes the momentum in the flowing stream of water. It also contains a built in axle which directly connects it to the shaft of the motor, therefore producing power by converting mechanicalenergy into electrical energy. It is connected to stationary blades by a sealed bearing in order to reduce friction.

Rear Cone:

The rear cone is at the back of the portable hydro turbine and its role is to keep the central parts of the turbine fixed with respect to each other, therefore reducing wobbling of the turbine blades. Indeed, it is attached by three M3 screws to the outer body and it is connected to the rotary blades with a sealed bearing in between to reduce friction.

Motor:

The role of the motor is to convert the Mechanical Energy produced by the stream of water as it rotates the blades into electric energy. It is sealed and protected from the water by using an Oring to seal the space between the nose cone halves and the stationary blades, and a lip seal between the bearing and the rotary blade shaft.

MATERIAL SELECTION

Blades - ABS (light, relatively stiff, high strength to density)

Outer Body - PVC (Scratch Wear and Shock Resistant)

Nose Cone - ABS

Handle - PVC to provide a higher friction coefficient so that it is easier to grab while in the water.

Screws - Stainless steel to prevent oxidization from water.

Threaded Inserts – Brass

PROCESS SELECTION

Component	Process
Outer Body	3D Print
Nose Cone	3D Print
Rear Stage	3D Print
Handle	-
Fixed Blade	3D Print
Rotary Blade	3D Print

3D printing appears to be a viable option for the rotary blade and possibly even for the fixed blade, which was originally split in half .A new 3D printing technology on the market may make 3D printing a clear outlier. This process known as Continuous Liquid Interface Production, or CLIP, is an additive manufacturing process similar to SLA, except that it does not produce separate layers that must be peeled from the base of the platform. Instead, this process continuously cures the resin without adhering to the base, thus reducing the printing time by 20-100 times. With the savings in total part count and printing time using CLIP, 3D printing would be the ideal process for manufacturing the rotary blade and the fixed blade.

PORTABLE HYDRO TURBINE (FINAL DESIGN)

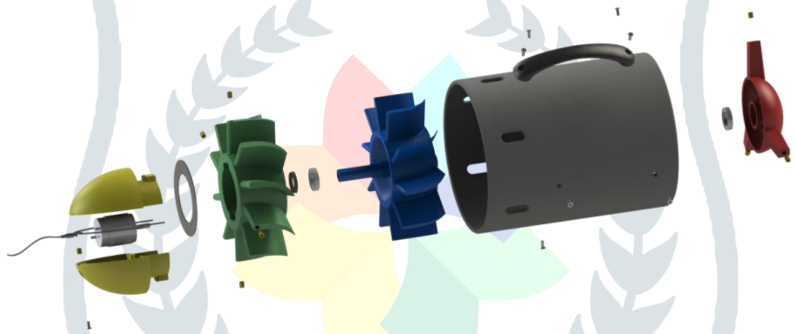


Figure: Final Design

ANALYSIS

To verify the design of our blades, we perform some basic finite element anaylsis using SOLIDWORKSsoftware.The first step was tosimplify the CAD model of the blades to allow for a quicker simulation, a 36 degree slice of the stage was used to simulate one of the 10 blades. Small features like the screw holes were removed but the fillet at the root of the blade was kept to avoid any stress singularities.

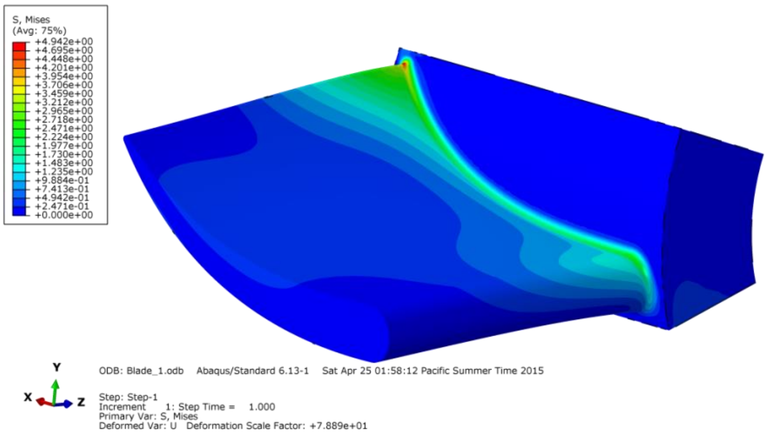
The test performed was a simple linear elastic, static simulation, the material used was nylon, defined by an elastic modulus of 2 GPa and a Poisson's ratio of 0.39.Anencastre boundary condition was applied to the two cut faces of the simulation geometry. The fluid force was represented by a pressure load acting normal to one side of the blade with a total magnitude of 27 N.

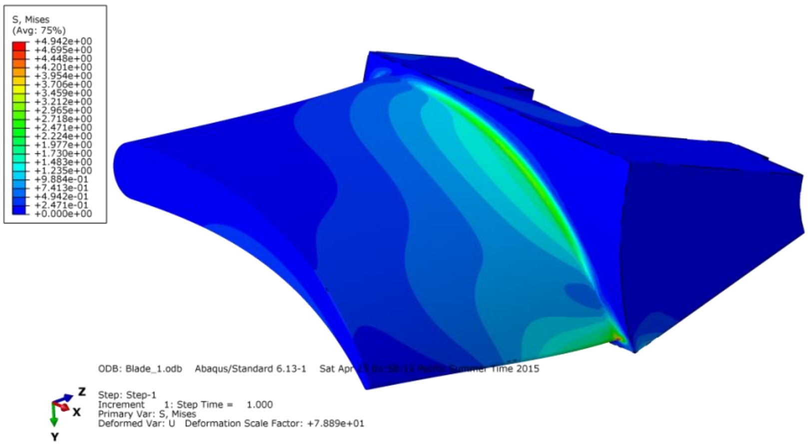
Mesh Details:

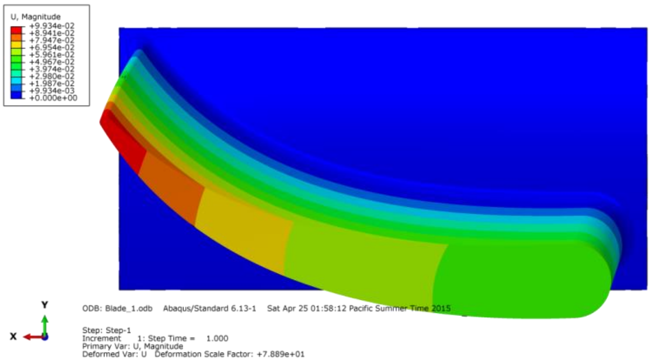
Because of the fairly complex geometry of the blade, a tetrahedral mesh was required. The mesh was refined manually in the vicinity of the blade with the element size ranging from 0.25 mm at the blade root all the way up to 5 mm at the inside of the support structure. Quadratic elements were used to avoid the artificial stiffening effect which occurs when using linear elements. The final mesh contained just over 600,000 elements and is shown below.

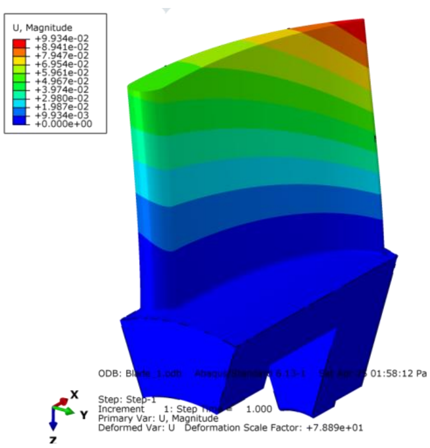
RESULTS

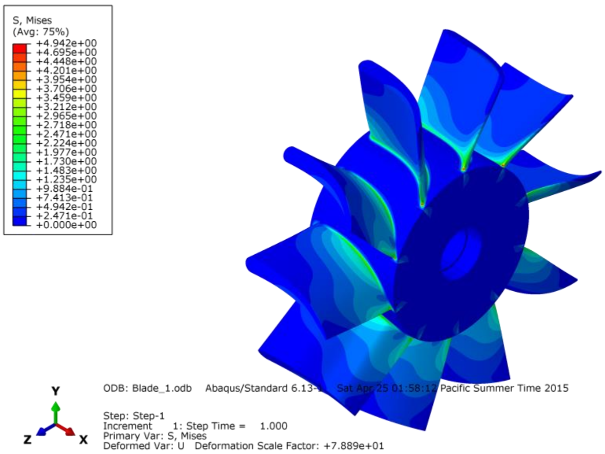
Some result plots are shown below, units are in MPa and mm for stress and displacement respectively, the results show that the maximum stress in the blade is around 4.9 MPa and the maximum displacement is just below 0.1 mm. These are both well within our design constraints.











CONCLUSION

The aim of this project was to create an affordable, and portable device to enable the capture of energy from a flowing stream of water in settings where no other power source is available such as during hiking, backpacking or scientific field studies. The final Hydro Turbine design can be made small enough to fit in a backpack with an outer radius of 15 cm (6 in) and a length of 20cm (8 in). It's weight of around 1.2 kg means it is light enough to be carried without too much extra effort. We have also shown through a number of analyses that the turbine is structurally sound and can deal with conditions much harsher than it's expected operating environment. According to some simple theoretical analysis, we believe that in a river with a reasonable flow speed our turbine can produce on the order 20 W.

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