

Whirlpool Turbine Phase 1 Report

Executive Summary

This Phase 1 report presents the preliminary design and analysis of a gravitational water vortex (whirlpool) hydropower system intended for low-head renewable energy generation. The objective of the project is to investigate the feasibility, functionality, and early design considerations of a small-scale turbine capable of converting the potential energy of water into usable electrical power in an efficient and environmentally friendly manner.

The proposed system operates by redirecting water from an elevated reservoir through a specially designed intake channel into a circular basin. The basin geometry induces a counterclockwise whirlpool, which drives a low-speed, high-torque turbine. As the turbine rotates, mechanical energy is transferred through a shaft and converted into electrical energy, which can be stored in a battery. Typical operating conditions for this type of system include a head of approximately 0.5–3 meters, rotational speeds between 30–150 RPM, and a power output range of 1–50 kW.

The turbine system is decomposed into three primary subsystems: the rotating turbine assembly, the water intake unit, and the turbine housing. The rotating assembly consists of the turbine head, blades, and input shaft; the intake unit shapes and directs water to form a stable vortex; and the housing supports and protects all components while maintaining proper alignment. The system's kinematics are dominated by rotational motion of the turbine blades and shaft, driven by the angular momentum of the swirling water.

A preliminary failure mode analysis was conducted to identify potential risks and guide early design decisions. Identified concerns include blade overload and wear from sediment, shaft torsional failure and fatigue, misalignment issues, and structural stresses and erosion within the whirlpool basin. Proposed mitigation strategies include optimized blade geometry, debris filtration, material selection, bearing support, uniform shaft design, and sloped basin walls to reduce impact forces and erosion.

Critical design parameters identified at this stage include material durability, blade number and geometry, rotational speed, shaft dimensions, housing configuration, and whirlpool basin geometry. These parameters will guide future modeling, analysis, and optimization efforts in subsequent project phases.

Overall, this Phase 1 report establishes the conceptual framework, system architecture, and key engineering considerations for the gravitational water vortex turbine, providing a strong foundation for detailed analysis and refinement in later stages of the design process.

Note: The executive summary was generated with assistance from an AI language model (ChatGPT) based on the content of this report.

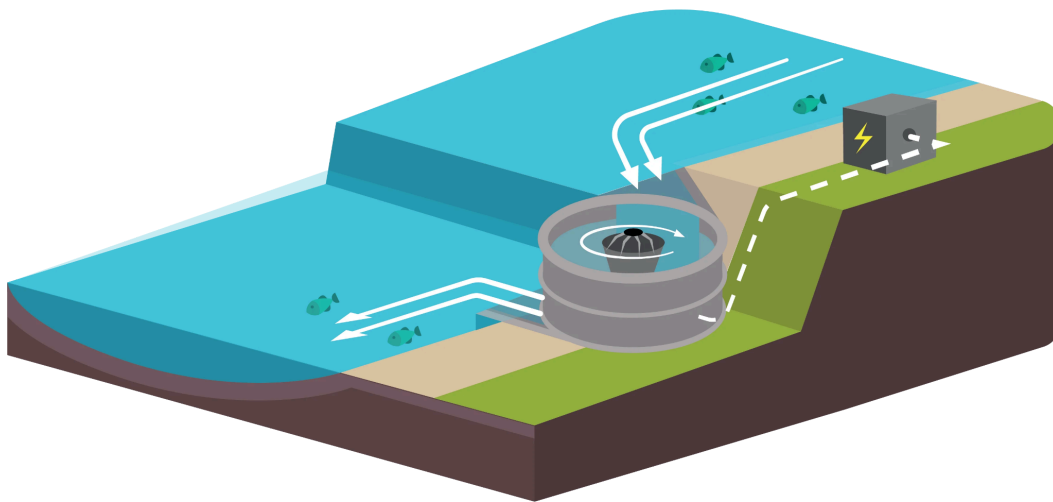
Video Presentation Youtube Link:

<https://youtu.be/ccR8WG-V6EA?si=mG5uwsc4-dWXKFoU>

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System Description and Function

Our system's overall function is to generate power using a whirlpool hydropower generator. In a real world scenario, water is redirected from a smaller dam, through a specially-shaped channel to a basin. The geometry of the basin causes the water to form a whirlpool, in a counter clockwise direction. As the water flows, the turbine blades are pushed along with it, generating power which is stored in a battery. The typical operating conditions include: a head (Water height difference) of about 0.5-3m, a high torque low speed 30-150 RPM, and a power generation of about 1-50 KW.

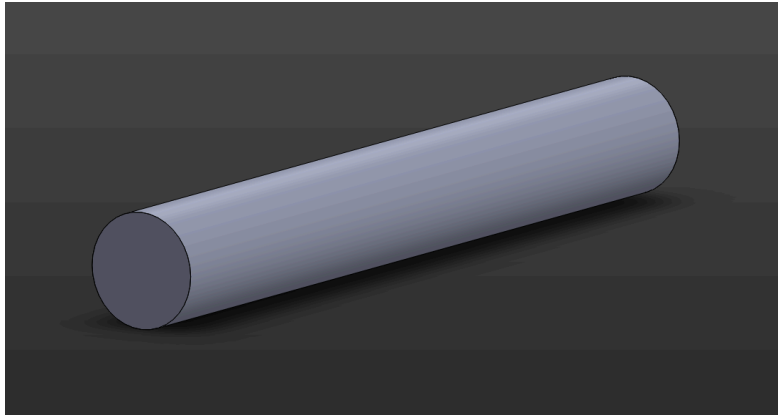


Component decomposition

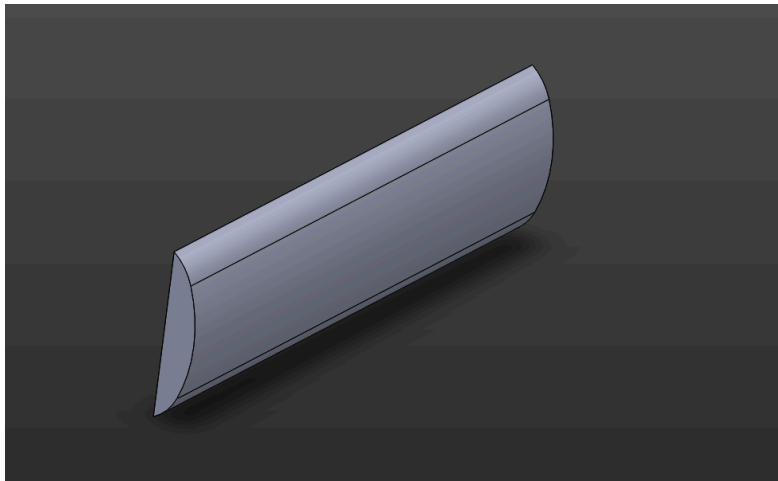
The key components of the water turbine are broken into 3 main subsystems, the rotating turbine head, the water intake unit, and the turbine housing. Within the rotating assembly there is the input shaft, the turbine head, and the turbine blades. For the water intake of the turbine there will be an attachment to the housing that creates a whirlpool that allows for the direction of water. Finally for the housing, it must hold everything together, broken into 3 unique parts and some repeated parts for assembly.

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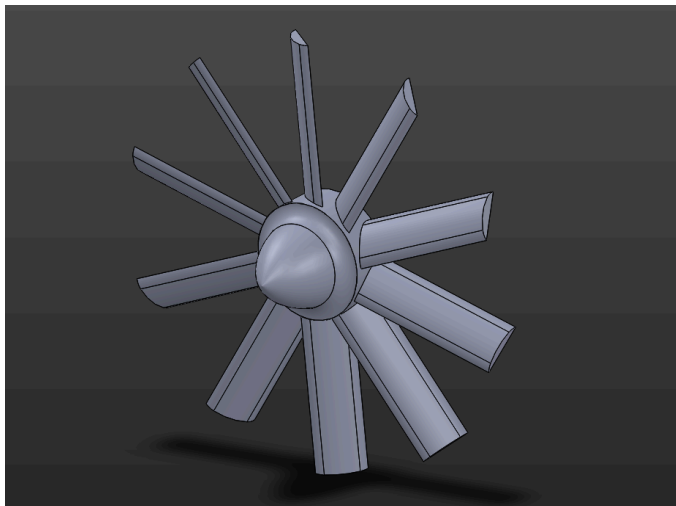
Shaft shown below



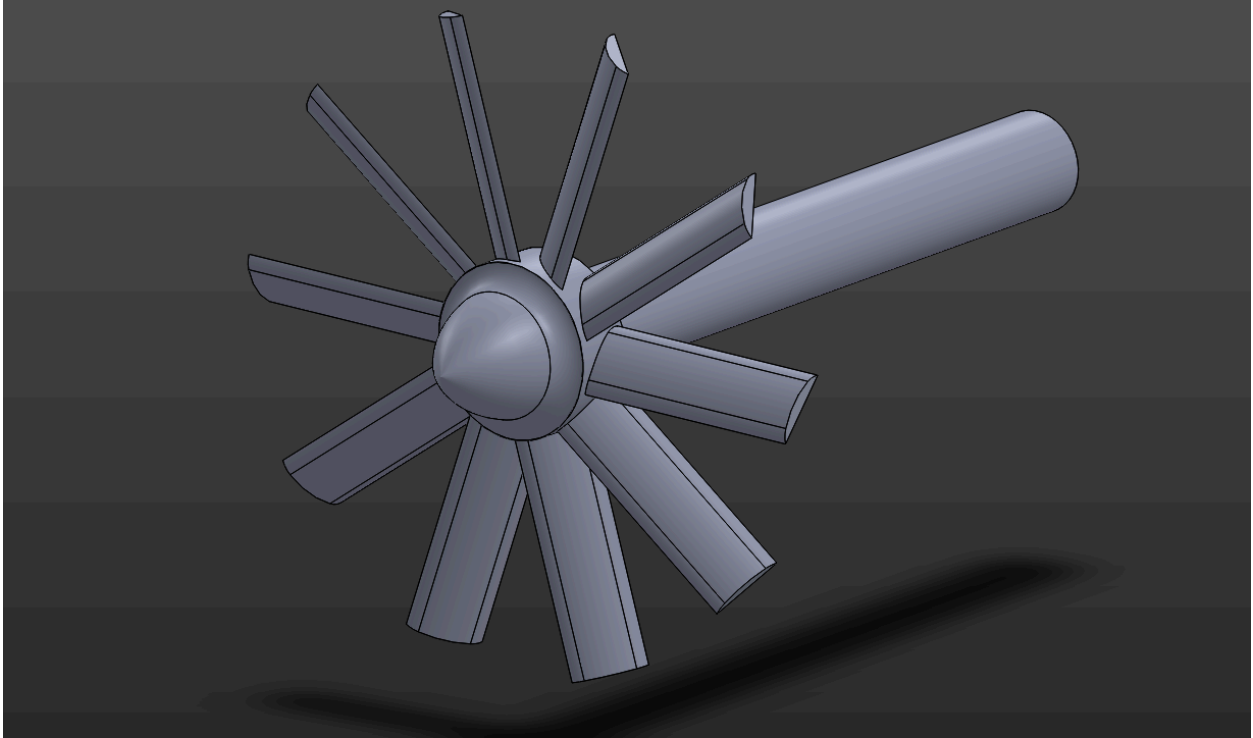
Singular turbine blade shown below



Turbine head with blades shown below



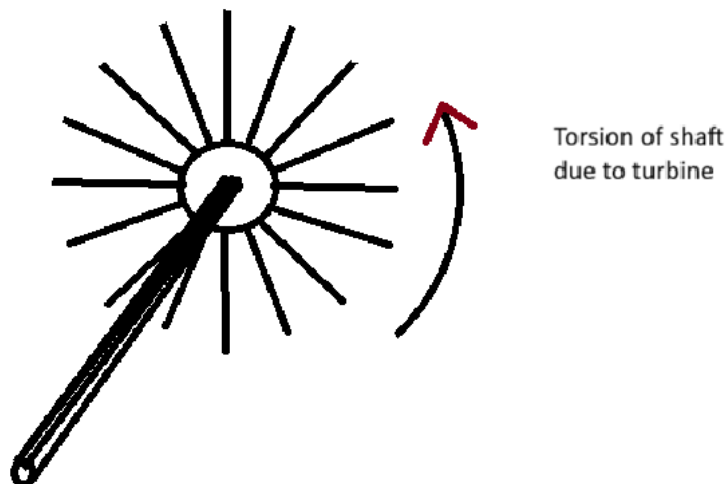
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Fully assembled turbine shown above

Kinematics

The two main components that have designated motions include the turbine blades and turbine shaft which perform rotational motion in the counter clockwise direction. The water flowing then generates electrical power from rotational motion.



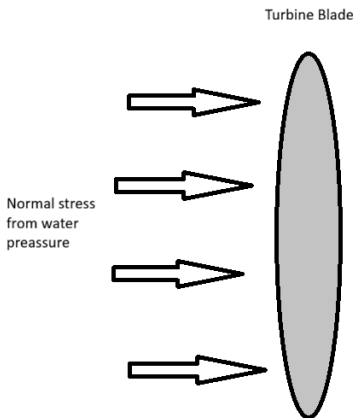
The main concept of this system is that there are two water reservoirs with an elevation difference. The potential energy from the higher stored water gets converted into mechanical work and then electrical energy. By directing the elevated water downwards and in a whirlpool

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motion we can get a turbine to spin. There is typically a 0.3-0.6 turbine to basin ratio. This is because a small ratio would have the turbine seeing too little angular momentum from the water while a large ratio would disrupt the vortex and increase energy losses.

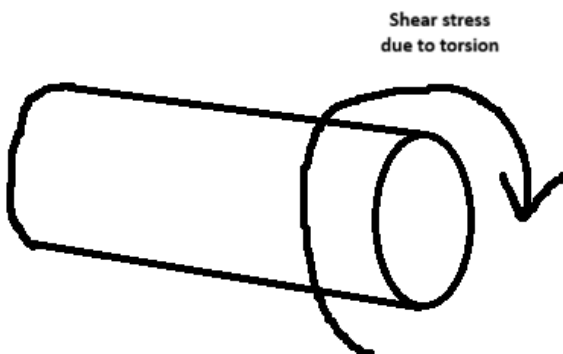
Failure Mode Analysis (Preliminary failure mode review)

- Turbine Blades
 - Static overload due to normal stress
 - Wear due to sand particles over time



Ways we can prevent static overload is by choosing a pitch/yawn for the blades to prevent a big difference of pressure because if the difference is too much then the forces from the water pressure is going to be much greater than the force of the pressure of the water leaving the turbine causing a lot of normal stress. The wear due to sand particles overtime can be prevented by using a mesh on the entrance of the whirl pool and on top, this would help get big chunks of debris away from the turbine and we can also do finer meshes in order get small chunks away from the turbine also this would help reduce sand particles from entering the turbine and doing damage to the blades over time.

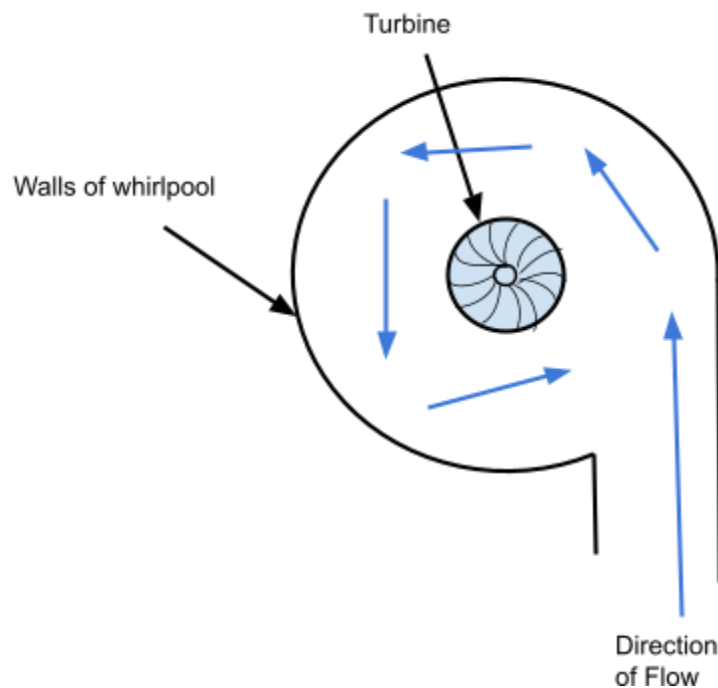
- Turbine Shaft
 - Shear failure due to torsion
 - Misalignments
 - Cyclical Fatigue



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To prevent the shear failure due to torsion we can use torsion damper and this would be a flywheel somewhere between the torsion source and the load, this would also help keep it away from the natural frequency of the shaft, another way can be changing the size and material in order to handle more torsion. To help the misalignment we can add a bearing supported and mounted to walls of the whirlpool or the ground, this would help by keeping it in place at that point and it would help with torsion effects also. We will prevent cyclical Fatigue by making the shaft uniform thickness throughout and curing the surface to not have any imperfection in the thickness.

- Whirlpool
 - Stresses from water constantly hitting the wall
 - Weathering and erosion of wall



The design to prevent stresses from the water hitting the wall by sloping towards the turbine because gravity will pull down the water so the forces will be directed at an angle to the wall not right at the wall making the stresses from the water reduce. This would also help the erosion and weathering of the wall because light collisions from the water means it will last a lot longer.

Critical design parameters

- Material durability (Rust resistant metal)
- Number of blades
- Blade Geometry (Blade size, Blade angle)
- Rotational speed (RPM)
- Shaft Geometry (Length,Diameter)
- Housing Geometry
- Walls of whirlpool (Length, Diameter, Angle of slope to turbine)

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