Introduction

The water vortex hydropower system is a new technology which utilizes the energy contained within a large water vortex as it is artificially created over a small head difference on a river.

How it works:
1. River water is channelled at the bank of the river and conveyed to a circulation tank. This circulation tank possesses a circular orifice at its base.
2. The combination of localised low pressure at the orifice and the concept of induced circulation at the tangential entry influences strong vortex flow. Potential energy is entirely converted to rotational kinetic energy at the vortex core which is then extracted by means of a vertical axis turbine.
3. Water is then returned to the river through the tail race.

Numerical Analysis will take a theoretical approach in considering the kinematic characteristics of the water vortex. Dimensional velocity profiles, vorticity and circulation can be derived from simplified forms of the Navier-Stokes equations.

Past Work and Findings

This research masters is a continuation of a final year project carried out at the Institute of Technology, Sligo in Civil Engineering (level 8). The project has successfully identified areas which require specific investigation. The following are some of the fundamental findings from this previous work:
1. The water surface profile of the vortex can be modelled mathematically and predicted accurately (see Fig. 6 (a)).
2. Optimum vortex strength occurs within the range of orifice diameter to tank diameter ratios (D/d) of 14% - 18% for low and high head sites respectively.
3. The vortex height varies linearly with discharge.
4. Linear correlations for H vs Q can be scaled accurately to prototype size using the Froude Model to be used as a design chart (see fig. 6(b)).
5. Maximum ideal theoretical power output = pQH, (H = Height of Vortex).
6. Maximum hydraulic efficiency should arise when the impeller velocity is half that of the fluid velocity.

Physical Modelling offers an inexpensive method to physically analyse vortex flow.

Aims

This system has only recently been introduced to the family of micro-hydropower technologies and still remains un-developed. Many questions relating to its design aspects, power output and efficiency still remain unanswered. Therefore research through design and optimisation is vital in ensuring the future potential of the technology is realised.

The project shall consider the broad range of areas requiring investigation including:
1. Optimising the shape and geometry of the structure to maximise vortex strength.
2. Standardising an understanding for the vortex velocity field which is crucial when considering energy extraction.
3. Optimising the design of the turbine to agree with the vortex velocity field.
4. Analysing the performance of the turbine in a full scale laboratory model.
5. Suggesting a number of empirical relationships to be used in the design of a plant.
6. Proposing a method to reliably predict the power output for the system.

Future research can then branch into more specific areas of study such as economical construction, costing and environmental impact.

Research Strategy and Method

To Optimise a Water Vortex Hydropower System

To optimise the performance of a water vortex hydropower system two distinct methods were employed. Physical Modelling, which utilises Particle Image Velocimetry (PIV), was used to study the input flow through the vortex core. Results were then used to numerically optimise the system. A laboratory scaled model was constructed and tested in a hydraulic laboratory. Numerical analysis were carried out using a commercial FEA code (Fluent). These results were then compared with the physical results obtained from the PIV tests. The design philosophy was to maximize the vortex energy to ensure maximum system efficiency.

Future Work and Anticipated Conclusion

It is expected that a number of key results will be obtained from the above research strategy. Each area will be interrelated in order to target the aims set out initially.

It is envisaged that the results obtained and assessed shall lead to three primary conclusions:
1. Optimised geometry – One which shall maximise the vortex strength for a given design head on a river.
2. Upper energy extraction – the turbine characteristics in both the horizontal and vertical plane will be designed to maximise hydraulic energy transfer.  
3. Design Approach – An engineer will be able to design a turbine at a selected site when the parameters of available head (m) and design flow (m3/s) are identified. This work is crucial when performing feasibility studies.

References