Design and Testing of a High-Efficiency Hydrokinetic Turbine

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ABSTRACT

There are numerous situations in which electrical power is required for remote locations not served by utilities or where existing electrical service is compromised. This paper addresses the feasibility of power extraction from local supplies of horizontally flowing water as the solution to this problem. The proposed system is based on a horizontally oriented version of a Savonius wind turbine. It features a simple, three-bladed design with optimized geometry that features very high efficiencies for energy production.

Keywords: hydrokinetic, water turbine, Savonius, tidal, river, stream

1 INTRODUCTION

There are numerous situations in which electrical power is required for remote locations not served by utilities or where existing electrical service is compromised. In these situations, it is desirable to have access to power that is not dependent on the consumption of fossil fuels or other consumables that need to be carried to the site. In addition, the use of consumable fuels can be problematic due to cost and environmental concerns. This paper addresses the feasibility of power extraction from local supplies of horizontally flowing water as the solution to this problem.

The proposed system is based on a horizontally oriented version of the Savonius wind turbine. It features a simple, three-bladed design with optimized geometry that features very high efficiencies for energy production. Referred to in this paper as the Waterotor, the technology enables users to generate power from flowing water in a number of environments, from small streams to ocean currents. One version of this device is shown in Figure 1.

2 WATEROTOR DESCRIPTION

The Waterotor design introduced in this document is an advanced Savonius type rotor, which is a stylized drum with optimally curved blades that efficiently captures water flow and extracts power. Fundamental to the invention is the way in which the Waterotor achieves maximum torque resulting in a high coefficient of power. This relates directly to power vs. size vs. water flow speed. Advantages over existing systems include:

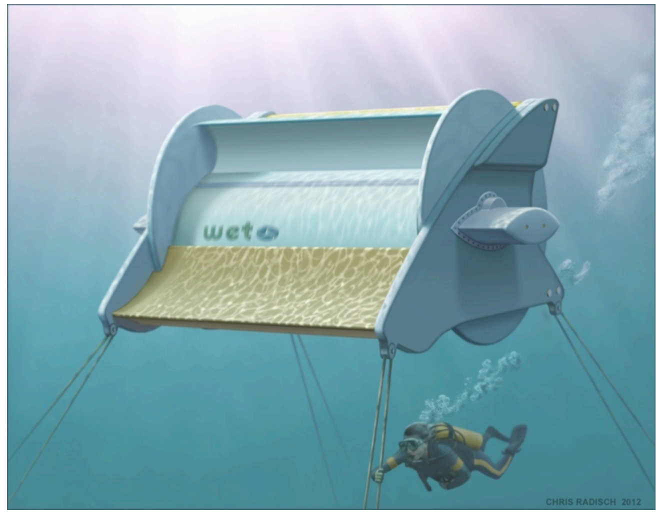

Figure 1. Artists conception of Waterotor

- Operates in slow-moving water; as low than 1.7 mph (.8 m/sec).
- Mobile, requires no bottom fixtures or foundation, only simple anchoring
- Strong yet simple structural integrity
- High coefficient of power
- Environmentally/marine-life friendly (no high speed spinning blades)
- Broadens a competitive market from very low to high water flow speeds
- Cost effective (simple to build and fully scalable)

The combined components and features for the Waterotor have been verified for maximum energy extraction for a water flow speed range from 1 mph to over 10 mph (size and generator match 'selection' per size and flow conditions). The efficiency rating is potentially over 30% - about the maximum expected efficiency for a Savonius rotor.

3 TESTING

The unique Waterotor design is the result of comprehensive wind tunnel testing and aerodynamic optimization exercises conducted in the past four years. The three-vane design shown in Figure 1 is based on parametric studies in the tunnel for optimum number of vanes, vane angle, thickness, leading edge geometry, and aft vane fairing shape. Three models were tested in the ViGYAN Wind Tunnel, located in Hampton, Virginia. The rotating

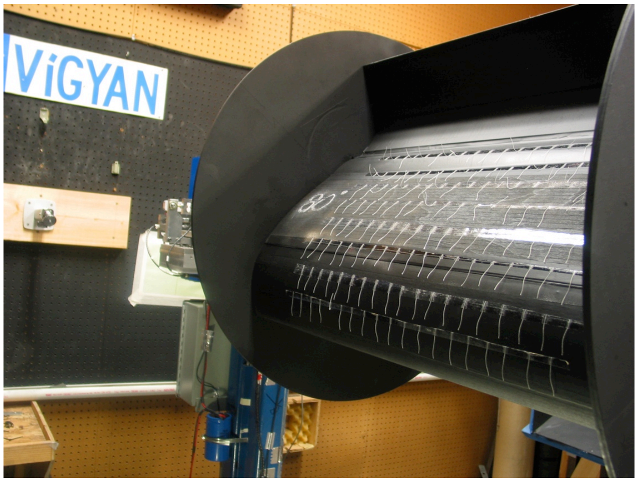

Figure 2. Waterotor wind tunnel model

models were instrumented with load cells for lift, drag, and torque using a dynamometer in order to apply loads for power calculations. A photograph of one of the models installed in the tunnel is shown in Figure 2.

The principal result is power coefficient (also referred to as the turbine efficiency), defined as:

Cp = measured output power/available power

Where

Measured output power is the power measured by the wind tunnel dynamometer.

*Available power=0.5*density * velocity^3 * frontal area*

The Cp is usually plotted as a function of turbine tip speed ratio (TSR), where

TSR= rotational velocity/ free stream velocity

It should be noted that efficiencies measured for such turbine devices cannot exceed 0.593, referred to as the Betz limit.

4 RESULTS

Among the interesting results for the series of tests was the effect of the size of blades. As shown in Figure 4, increasing the size of the blades for a given configuration increases the power coefficient. Other tests provided guidance on the number of the blades, specific geometry, and other aspects of the aerodynamic characteristics. The final shape of the turbine as shown in Figure 2, provides a turbine efficiency of 22.5% as shown in Figure 4.

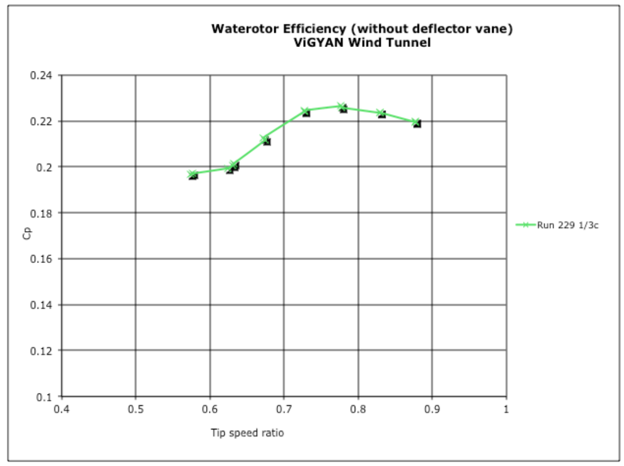

Figure 3. Waterotor efficiency as a function of tip speed ratio

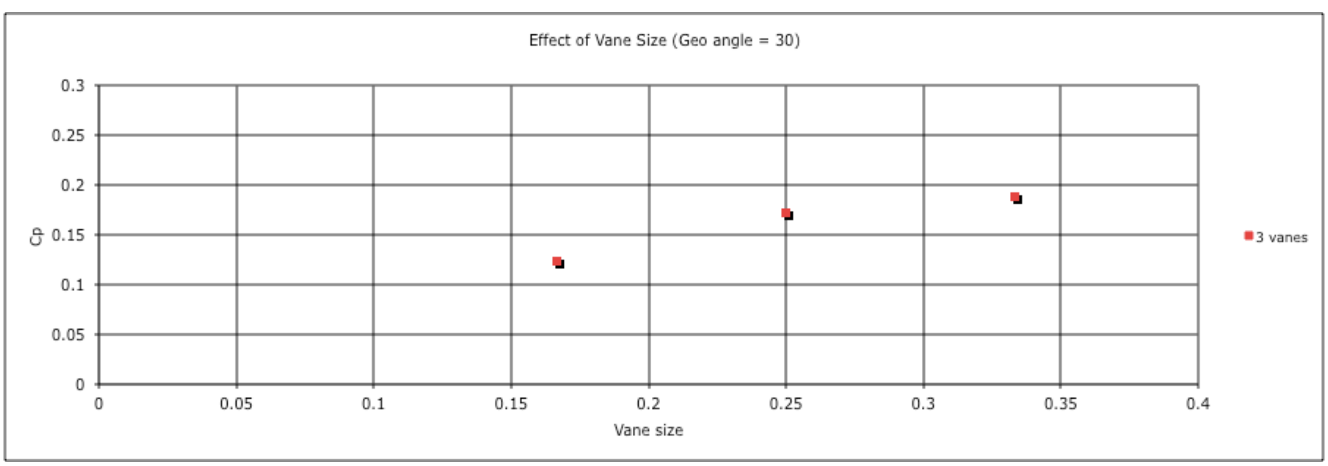

Figure 4. Effect of vane size

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The pre-production system , which as been tested in the water, uses a deflector to capture more water and provides an efficiency (based on the original turbine frontal area) of about 30%.

5 CONCLUSION

A series of wind tunnel tests was done to guide the design of and document the hydrodynamic characteristics of a hydrokinetic water turbine. Guidance on the number of the blades, specific geometry, and other aspects of the aerodynamic characteristics was obtained and used to finalize the design. The current version of the device, called the Waterotor, generates a power coefficient (efficiency) of about 22.5%. The actual implemented system, which also uses a deflector, operates at about 30%.