More Efficient Hydrokinetic Turbines

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ABSTRACT

The efficiency and cost-competitiveness of renewable energy are key to its long-term viability. Usually, the most efficient form of renewable energy is water because of its high density of energy content relative to wind and solar. This paper presents a way of making hydrokinetic energy much more efficient based upon the results of Computational Fluid Dynamics (CFD) modeling.

Keywords: hydrokinetic, underwater turbine, computational fluid dynamics, shroud, propeller

BACKGROUND AND DEFINITIONS

Hydrokinetic refers to two forms of energy: tidal and run of river. They both have the characteristics of obtaining energy from currents of water.

CFD is a tool that enables one to test inventions rapidly before building them.

The Betz equation is a formula that shows that any propeller-based turbine has a maximal theoretical efficiency of 59%. In fact, most propeller systems have efficiencies in the 30-35% range.

A shroud is a term for an airfoil shape that surrounds a turbine, whether it is a jet engine, or a set of propellers. The Betz equation does not apply to shrouded turbines.

TECHNOLOGY DESCRIPTION

It is well known that shrouds and funnels have the potential to concentrate energy contained in a flow, and some attempts have been made to use them for hydrokinetic turbines, as in Figure 1. Notice that there are some outstanding disadvantages: huge length, weight, hard to manufacture, and, judging from principles of fluid dynamics, not adding much efficiency.

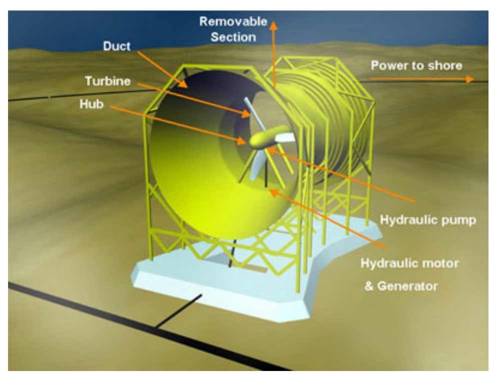

Figure 1: Lunar Energy Funnel

The increase in velocity is a powerful way to increase energy output. The equation for flow of a fluid is P in watts = ½ x density x area x velocity cubed. After that, one adjusts for efficiencies. Since power output is related to the velocity cubed, a small increase in velocity is cubed and becomes of major importance.

One of the reasons it is not so efficient is that, like Venturi tubes, its acceleration of flow velocity occurs over a large distance in the x-axis, but its velocity is not much concentrated in the plane of the blades perpendicular to the direction of flow.

Figure 2 is an example of an outline airfoil that resembles a funnel. Note that the increased velocity in the highest red region is very small, and most of the increased energy is diffused over a large area in light blue.

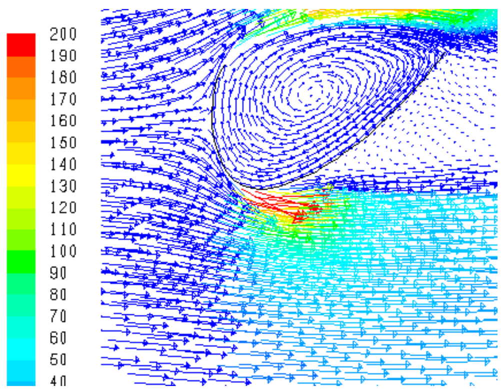

Figure 2: CFD of a funnel-like structure. Red is highest velocity; dark blue is the lowest.

The author tested a new concept with CFD analysis. That concept is making much smaller aerodynamic structures that are much more efficient. A large increase in power is possible because the structures, called outline foils, cause concentration of increase velocity in the plane of the blades. This was granted as patent 8188611 in the US.

By contrast, the velocity profile of what we call a "C foil" in Figure 3 shows a much more extensive red area that reaches to the point labeled 172, around 3-4 times greater in a radial direction than the red area in Figure 2, even though its funnel appears much less developed on the inlet side. Therefore, it should achieve much more energy production in a small space than the long funnel shown in Figure 1.

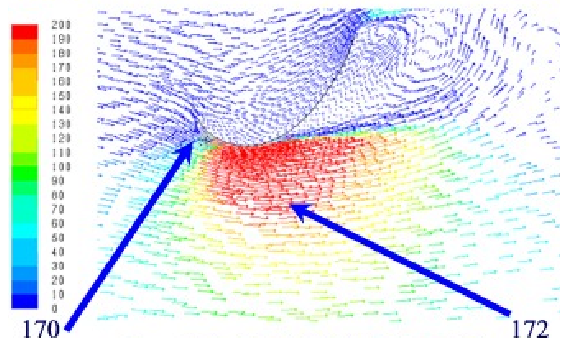

Figure 3: CFD of a C foil. From patent US 8188611.

In fact, when one models this class of airfoil in a condition of a likely product of 10-meter diameter blades, one can see in Figure 4 that it produces a zone of higher velocity perpendicular to the flow. The outside velocity of the water is 1.0 meters/second. The water inside the foils is accelerated to at least 1.3. (The scale goes from low to high velocity.) This is for 10-meter blades.

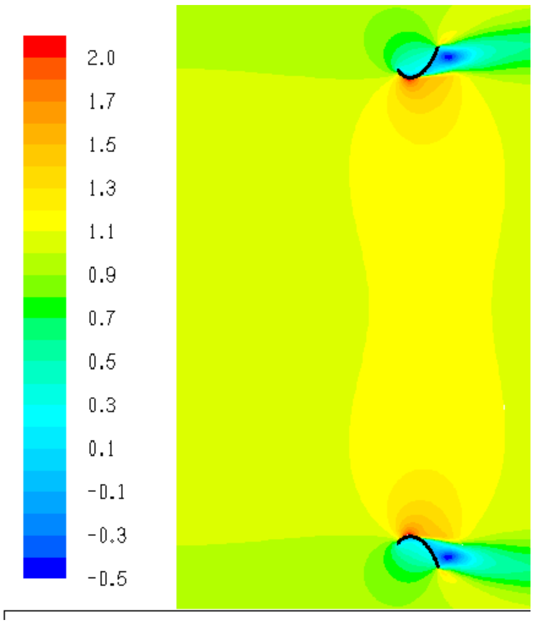

Figure 4: CFD of a C foil shroud with 10 meters diameter

For the blades to take full advantage of that flow, a second step is required—exact geometrical positioning of the propellers. Figure 5, done for a smaller diameter turbine, shows that a small change in position of 5 centimeters can result in a change of power output of over 100%.

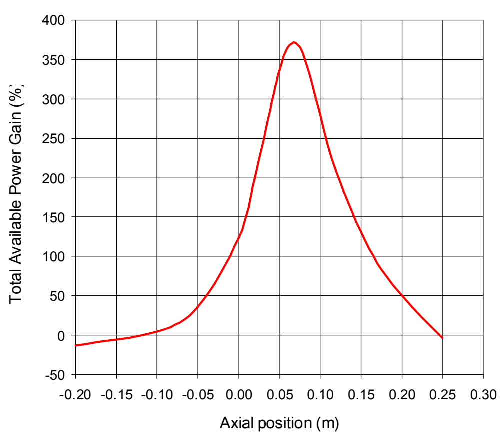

Figure 5: Percentage increase of power gain plotted against axial position of the propellers in relation to the shroud.

The third step, explained in a patent pending in the US, is to change the propeller design in such a way that it takes full advantage of this unique environment by increasing the ability of the tips to convert the higher velocity there more efficiently than current blade designs. Figure 6 illustrates how the final product would look.

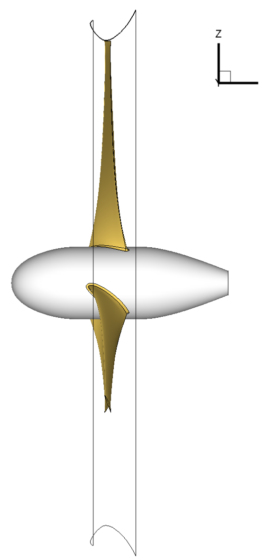

Figure 6: Blade and shroud combination

Independent simulations by the US Navy using 10 meter blades and one of the foil shapes mentioned in the patent gave the result of a 50% increase in power output.

In addition to that advantage, our simulations show that the turbines will start at lower flow speeds because the effective velocity at the blades is higher and better utilized.

CONCLUSION

The invention described here has the potential to address several significant issues holding back the development of hydrokinetic renewable energy.

-It starts at lower speeds, and thus opens up more areas of the world where this technology is applicable.
-It reduces the cost per kilowatt
-Its shroud is small and cheaper and easier to produce.
tic power.

-The shroud provides a platform for suspending a meshwork that keeps out fish. This solves an important barrier in many countries to the development of hydrokinetic power.