Modeling the Twisted Savonius Wind Turbine Geometrically and Simplifying its Construction

Investigate the shape and simplify the construction method of the Twisted Savonius Wind Turbine

Background

- Currently, most wind turbines are Horizontal Axis (HAWTs) and found in windy areas away from the majority of the people who use their power.
- Vertical Axis Wind Turbines (VAWTs) are rarely used in industrial applications because of their radius inefficiency in the open plane.
- The most logical place to generate power is near to the location of use as possible, to reduce transmission losses.
- The best place near buildings for wind turbines is on top of them, because higher wind speeds are found at higher altitudes and airflow around buildings directs the air onto them [4].
- Wind is very turbulent around buildings because they interrupt airflow.
- Therefore, placement in the path of the strongest, turbulent winds and use of a turbine that is operable in turbulent winds are essential.
- Traditional HAWTs and most VAWTs cannot operate in turbulent winds.
- One VAWT design has shown a lot of potential in turbulent, rooftop settings: the Twisted Savonius.

Mathematical tricks can be used to accurately build the turbine in the two-dimensional and three-dimensional formats, by manipulating a coordinate point calculated from the top view in Gx.

The Turbine in Gx

Using ellipses, proportional points, loci and traces, this model of the Twisted Savonius VAWT was developed. It is fully constrained mathematically, facilitating dimensional adjustments, and can be animated to spin as if in operation or to twist and untwist from the simple Savonius design.

Unrolling the Blades

Because of the geometric planar relations of the blade shape, it cannot be unrolled into a flat surface, like a sphere. Instead, triangles were used to approximate the turbine’s shape in the top view model. Incorporating the vertical dimension, hidden in this view, the side lengths of these triangles, using the Pythagorean Theorem, allowed the turbine shape to be approximated by a flat surface which can be folded into the turbine shape. Using more triangles for this approximation produces a more accurate figure that can be folded up to create what is essentially the actual shape of the blade. With enough triangles, this model should be able to be rolled onto a turbine frame without folding at every triangle, but this step has yet to be completed due to the complexity of the models. Some sample triangle side lengths from the 32 degree side approximation are shown below, calculated from the top view, then constrained on the unrolled model with the Pythagorean Theorem incorporating the height (a).

Calculations:

\[ r = \frac{a}{2} \]

\[ \theta = \frac{\pi}{4} \]

\[ h = r \cos \theta \]

\[ a = r \sin \theta \]

\[ \text{Area} = \frac{1}{2} \times r^2 \]

\[ \text{Perimeter} = 2r + 2r \sin \theta \]

\[ \text{Volume} = \frac{1}{3} \pi r^3 \]

\[ \text{Surface Area} = 2 \pi r^2 + \pi r \theta \]

Finding the Surface Area Limit

Triangle approximation models were created using 4, 6, 8, 10, 12, 14, 16, 18, 20, 24, 28, and 32 sides. The symbolic area of these figures could not be calculated by Gx (not even an individual triangle could be), so the area and perimeter approximations were used, each twisted π/4 radians. This minimizes squeeze and complexity of construction while maximizing twist, and therefore functionality.

The Squeeze

It was found, through observation of these graphs, that the squeeze can be most efficiently avoided by stacking four sections of turbine, each twisted π/4 radians. A graph of the surface areas follows.

Abstract

The dog-based Twisted Savonius Vertical Axis Wind Turbine (VAWT) has shown promising applications for use on the tops of buildings, enabling clean energy production at the site of its use, virtually eliminating transportation losses. Unfortunately, the turbine’s shape is very complex and three-dimensional because of its twist, requiring complex machinery to construct. I was able to model the geometry of this shape with the symbolic Gx software and make it seem as if it is in a three-dimensional plane.

Goals

- Develop a model of the twisted Savonius turbine that will allow for the construction of the turbine, including the blades, hub, and tower.
- Use the model to predict the performance of the turbine.
- Compare the performance of the twisted Savonius turbine with that of a traditional horizontal-axis wind turbine.

Discussion

- Discovering and modeling the squeeze has led to knowledge of how to build the geometry of the turbine.
- The turbine has a slightly simplified construction method, by limiting the sections to true Savonius shape.
- It also allows for accurate twisting of the turbine, as found in previous studies that go beyond the physical limitations of the materials alone.
- The visuals created enable proper visualization of the turbines and can be combined with pictures in Gx to create renderings of how the turbines would look on buildings.
- Knowing the surface area of the blades allows cost estimates to be made, based on the materials used.
- A 2 meter tall blade (for a 3 meter turbine) could be built from the triangle approximations for under $250 (with axis-mount, without gears, generator, electronics) and most of this cost would go toward the turbine’s metal frame.
- The cheaper cost and simpler construction open the door for widespread use of the twisted Savonius Design.

Citations