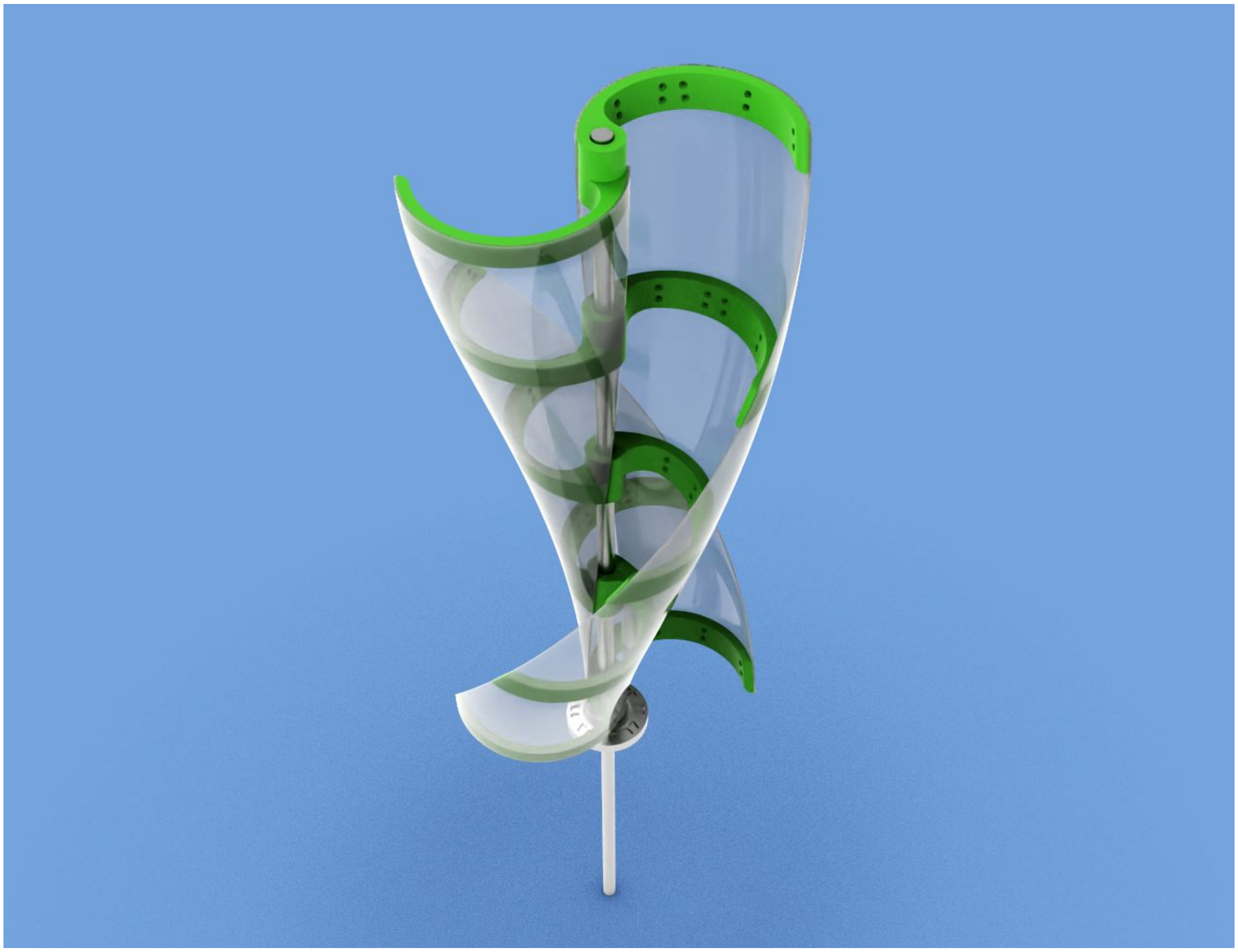
Wind Energy Kit: *Economic Production of Helical Savonius Vertical Turbines for Natural Disaster Relief*

SME Student Chapter S125|Western Washington University|College of Science & Engineering



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Contents

Project Statement

Following a natural disaster, affected areas often experience massive failure in the infrastructures of communication and power. The short term solutions to these problems include small gas powered generators and electronic based handheld communication devices that must be recharged regularly. However, these solutions can become difficult as shipping energy sources can be costly and difficult due to their range in sizes and complexity in setup. Therefore, sustainable and renewable energy sources are in high demand during times of plight. A sustainable form of energy is crucial for the use of devices that request help or relay messages from afar. For this reason, of the seven forms of renewable energy sources, wind energy was the main form of clean, renewable power taken in consideration for this design.

Unlike other forms of renewable energy such as solar or hydroelectric, wind energy can be accessed in almost any climate. Wind speeds ranging from 3 to 15 mph are common across the globe, and this energy can be harnessed to create cheap and reliable sources of electricity. The advancement of composite technology has increased the magnitude of weight savings in highload applications such as large-scale wind harvesting. This project aims to provide a wind turbine design that allows for rapid changes in its design, not limited by large upfront tooling costs such as molds or fixtures.

Functionality & Durability

While horizontal wind turbines are typical in large commercial scale sustainable energy power generation scenarios, they are not realistic or economic solutions for average consumers. Wind speed and direction are too unpredictable at smaller scales and at lower altitudes rendering traditional turbines ineffective. Vertical wind turbines, where the main rotor shaft is set perpendicular to the wind direction, allow for the generation of electricity regardless of wind direction and require a much lower wind power input to initiate rotation. A vertical Savonius type turbine is unique in that it can start at slow wind speeds, be positioned independent of the wind direction, operate in a wide range of wind conditions, emit little noise, be compact in size, and house all of its electronics beneath the axis and generator. The turbine itself functions most commonly on a vertical axis and is formed in a helical configuration with two blades twisting upwards around a central rotor shaft. The helical form increases the turbines efficiency by minimizing pressure pulses. These characteristics make this wind turbine ideal for the purpose of this design challenge.

This wind turbine will be shipped to disaster affected areas in an all-in-one kit that can be easily assembled by anyone and can immediately begin providing power assuming an exposure to wind. The turbine itself functions on a vertical axis and is formed in a helical Savonius design with two blades. Plastic sheets, laser cut to custom sizes, will also be provided for use as the surface of the turbine blade. These sheets are flexible and will be shaped around the 3D printed blade guides, which form the skeleton of the turbine from the central axle. In addition to this kit, an STL file of the blade guides, as well as a pattern for the blade sheet, will be provided to the public. This allows users to create their own turbine as every component in this kit is available to purchase online or local. Allowing the design to be open source lets users 3D print guides, replace a damaged component, or modify the scale of the turbine.

- **Assembled out of a all-in-one included kit**
  - 12x 3D printed blade guides
  - 1x USB stick containing CAD files for the blade guide
  - 1x Laser cut plastic sheet
  - Hardware (bolts and nuts, wires, zip-ties)
  - 1x Shaft
  - 1x Magnetic Suspension Bearing Block
  - 1x Generator
  - 1x Charge controller + wires
  - 2x 15000 mAh lipo batteries
  - Manual

Turbine Power Specifications

- Beginning Wind Speed: 1.3 m/s
- Cut-in Wind Speed: 2.5 m/s
- Rated Wind Speed: 11 m/s
- Rated Voltage: 12 V DC
- Max Power: 450 W
- Max Wind Speed: ≤40 m/s
- Rated Power: 400W
- Gross Weight: 30 lb

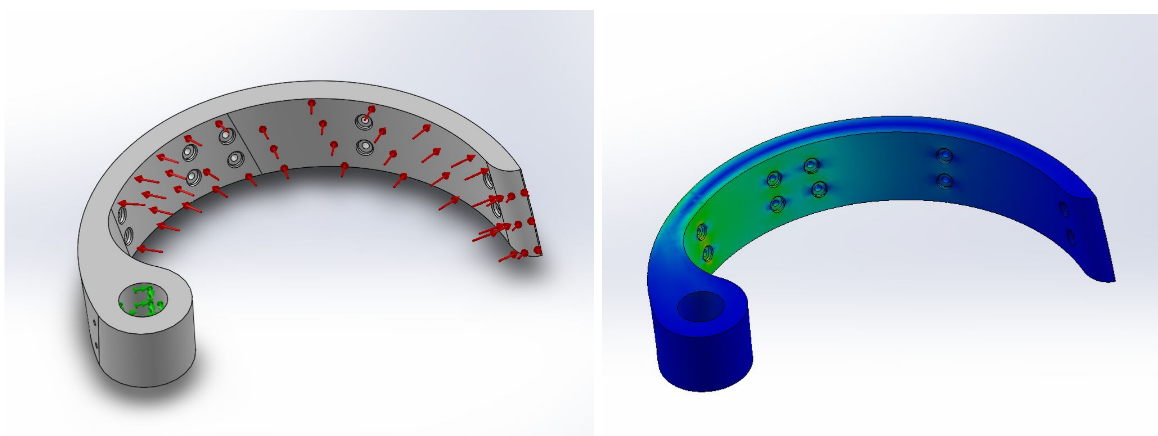

Figure 1 - FEA fixturing and wind pressure loading visualized via green and red arrows, respectively. Simulated in SolidWork stresses did not exceed 50MPa modulus of PLA

Cost Benefit & Value Analysis

Using 3D printed blade guides over injection molded parts saves tooling costs, and allows for much greater flexibility in size-scaling, depending on the size of the 3D printer bed. The plastic sheets that are used for the turbine blades are relatively inexpensive compared to traditional molded plastic blades, and can be custom cut to accommodate various turbine sizes. With this kit, the material or component selection is not set in stone. All the components are available to purchase online if the end user would like to replace a broken part or customize their turbine. Users are even able to purchase their own 3D printer, filament, and PTFE sheets if more turbines are desired. PTFE sheets can be purchased online as roll stock and sheets can be as low as $5 per sheet, cheaper alternatives can be substituted.

Utilization of DDM Materials

FDM manufacturing allows for rapid manufacturing, prototyping and iterations of the turbine blade guides as well as the selection of unique materials for specific requirements such as strength and resistance to environmental wear. It is recommended to tailor the selection of each material to the specific situation in which the turbine is being used. PETG demonstrates strong weatherability and strength qualities that are favorable for use in adverse outdoor conditions [1]. When compared to PETG, PLA can be recycled through Industrial composting in 1-3 months and therefore would be preferred for higher production volumes [3].

Utilization of DDM Processes

Fused Deposition Modeling (FDM) is an additive manufacturing process that uses a thermoplastic filament, which is heated to its melting point and then extruded, layer by layer, to create a three dimensional object. FDM allows for a large amount of freedom and versatility in the manufacturing process despite complex designs. The selection of FDM manufacturing for this wind turbine allows for the product to be produced cost effectively while minimizing cycle times when compared to composite based processes.

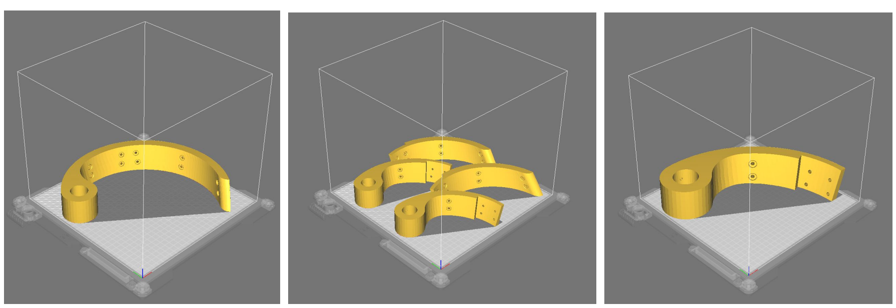

Figure 2 - Left: Full blade guide, no split at 120% scale
Middle: Two blade guides in the split configuration 100%
Right: 180% scaled blade guide segment in split configuration
(Cura Software was used to generate images)

By adopting 3d printing as the primary means of manufacturing these components, different configurations and scales of the turbines are possible. Initial designs had each individual blade guide to be manufactured as a single component, fitting onto a standard print bed diagonally, Figure 4, and producing a final turbine diameter of roughly 20 inches. By using a lap joint midway through the part, either more parts can be fit onto each print bed as shown in the middle (Figure 4), or the parts can be scaled up to 180%, increasing overall turbine diameter to 30 inches and increasing working area and thus proportional power output of the turbine by 325%.

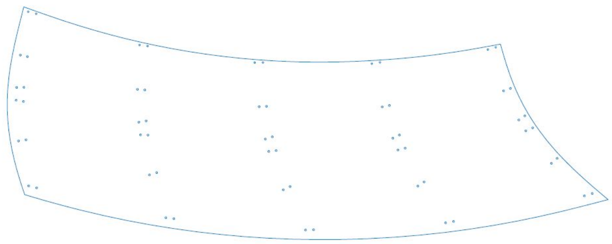

Figure 3: Flattened blade pattern to be laser cut from common plastic sheet

Design Integration & Innovation

The blade design is a helical Savonius, allowing the turbine to spin easily through the drag forces applied by low-level wind. A study by Saha and Rajkumar identified that as the twist angle of Savonius wind turbine blades is increased, so is the general efficiency and smooth operation of the design [5]. Helical blades result in a more constant torque than straight blades, which reduce the amount of maintenance required, improving the life-space on the turbine. By introducing a simple 3D printable solution to shaping the plastic blade sheet component, the Savonius turbine becomes a practical, affordable and easily manufacturable answer to the pressing problem of generating power in areas with either minimal or destroyed electrical infrastructures.

Marketing

Electrical power is absolutely necessary for communications during natural disasters. However, it is often the case that local electrical grids fail during these events. Energy sources that harvest readily available renewables, such as wind, are increasingly valuable for emergency situations. The wind turbine kit will be available for immediate shipment to areas that are affected by a natural disaster. Donation of supplies and generators will be encouraged by engineering companies as to promote charitable acts, resulting in tax write offs, and to advertise good personal relations by the company donating. The design of the turbine and the CAD files, Figure 6, will be shared openly on a website so that as many as possible can access the plans.

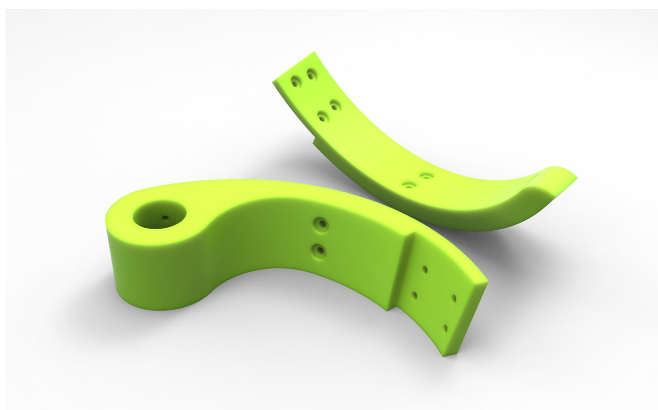

Figure 3: Rendered model

Social and Environmental Impact

By manufacturing this device, entire communities affected by natural disasters will gain the ability to have a reliable source of power through harnessing a renewable energy source. This power can be used for essential things, such as hygiene, communication, and safety. Through utilizing PLA filament, we can keep negative environmental impact to a minimum.

Prototype

Figure 5 - Prototype (3:8 Scale). Built at the WWU Makerspace. Tested to 200 RPM in multiple orientations confirming helical Savonius design.

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