Fall Midterm 1 Report

Team 9
Power Generating Sub-System of Kite Power Generator

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Date Submitted
10/21/2016

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ABSTRACT

The purpose of this project is to design a kite based water collector for remote islands that generates power. To generate power, the kite will be tethered to a permanent magnet within a housing that contains an electric coil. As the kite is subjected to a wind load, the kite will pull the magnet through the coil. When the load decreases, a spring or hydraulic will force the magnet back through the coil housing. Electricity is generated each time the magnet slides through the magnetic housing. The kite will also collect water from the moisture in the atmosphere. The kite will condense the moisture which will then travel along the tether of the kite to an aquifer.

ACKNOWLEDGMENTS

Thank you to Jeff Phipps for making himself available through email to answer our questions in regards to this paper and for coming up with the original idea for this project. We would also like to thank Dr. Shih and Dr. Gupta for presenting us with this project and giving the opportunity to execute the desired tasks.

1. Introduction

The idea is to achieve power generation from a water collecting kite in remote island areas. The purpose for this project is to provide affordable power for areas that do not have a major reliable source for power. The idea is to harness the energy of the wind without constructing a permanent wind turbine. Conventional wind turbines need a permanent setup and require a high amount of maintenance. Other forms of alternative energy such as solar power can be very costly to initially install and can only generate power when there is direct sunlight. Kite power allows for more maneuverability and less maintenance due to less mechanical parts. Placing in an area like the Greek Islands, where there are constant prevailing winds also allow for kite to be in the air and generate power at almost all times.

The kite will be of relatively simple design and construction, as to make the product inexpensive and economically appealing. The simplicity of the design will warrant very little service and costs resulting in maximum in-service time. This design will also allow the kite to be retracted at times when necessary, thus making it less intrusive to the surrounding environment.

The kite will generate power by oscillating a magnet inside of an electrical coil. To get the kite to oscillate and still sustain flight, combination gearing and/or cam design will let one end of the kite go while pulling on the other end causing a teeter-totter like motion. This will vary the angle of attack of the kite thus varying the lift force and tension on the string. In combination with the spring connected to the magnet pulling it back down, and the changes in the lift force, the magnet will oscillate. There is also an issue of sustaining equilibrium in the roll axis of the kite. To achieve this a tail design could be used or another gearing/cam. This, however is outside of the required project scope.

The power generator consists of a housing that has a top and bottom and a hollow interior. The coil will be situated within the housing, where the magnet will consistently pass through. A spring will be fixed on one end to the housing with the other end of the spring connected to the magnet (Figure 1). As the kite is subjected to a wind load, the magnet, connected to the tether of the kite, will be pulled through the coil housing. As the wind load decreases, the spring acts to restore its natural state by forcing the magnet back through the coil housing. The housing is attached to a swivel port, allowing the housing to spin on its axis depending on the direction of the wind and the flight path of the kite.

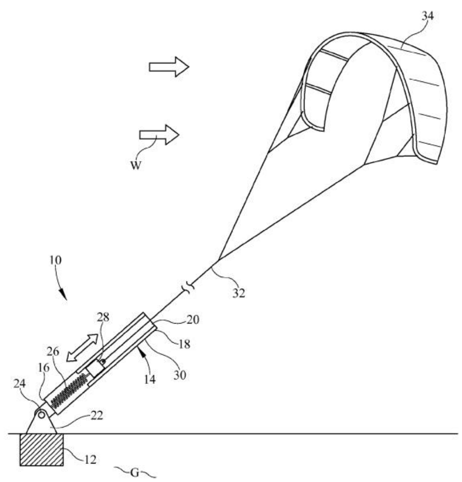


Figure 1. Jeff Phipps Pogo Solenoid Patent [1]

2.0 Project Definition

In this section background research, will be presented about various companies and what they have done that is like the design goals that are being pursued. It will be important in future endeavors to have reliable reference material to fall back on to check what will work. In addition to the background research, a need statement will be defined, the constraints will be clearly listed, and the methodology of how the project will be approached will be laid out.

2.1 Need Statement

The need statement for this project is as follows:
To design a power generating kite that will also deliver clean water to rural mountainous areas.

2.2 Background Research

2.2.1 Kiteship

In regards to harnessing power from the wind via the motion of a kite, it is important to take note of other companies who have successfully built such mechanisms. One in particular is Kiteship[2], a company that utilizes sail-kites on freight commercial ships as an aid to pull the ships in their journey across the ocean. The company also holds the world record for the largest kite to pull a land vehicle and largest vessel pulled by a kite. To put things into perspective, a13,000-square-foot kite allows for fuel costs to be decreased by 10-20% on a normal-sized commercial vessel. This directly translates to $400,000 in savings per year. Thus, kite-sails are a more cost-efficient and energy-saving green alternative to transporting traded goods across the world. It can be taken note that the bigger the kite, the more wind energy will be generated and the higher the kite, the stronger the winds. Utilizing this information in further projects will be deemed useful in generating more wind power through the motion of a kite.

2.2.2 Skysails

Skysails[3] is another company that serves as a more efficient and green alternative to utilizing wind power than the conventional sails propulsion systems. The flying towing kites generate 25 times more power than the sails previously used. It works through the control pod which is used to steer the kite in front of the vessel to help pull it in the right direction (Figure 2). The kite and control pod are connected via a towing cable covered by a coat of synthetic fiber that serves as communication for steering between the pod and kite. It is interesting to take note that there is no need for a launching aid such as a balloon filled with helium since the kites are intended to be used in the ocean where there are strong winds. The winds are monitored in direction and velocity to achieve optimal propulsion from the kites.

Figure 2. Skysails used for towing boats so no electricity is used

2.2.3 Strandbeests

Strandbeests[4,5] are giant artistic structures made from PVC piping, wood, and fabric that are self-propelled. Theo Jansen created the first Strandbeest in 1990 and he continues to create them today. Over the years they have evolved into more complex and lifelike creatures. They are self-propelled, using wind power to move around, and have specialized adaptations to help them "survive" on the beach. The Strandbeests have a "spine" that runs down the middle of the structure and acts as a crankshaft for the legs. The legs are designed so that there are always multiple legs supporting the structure at any one time. The more complex Strandbeests (Figure 3) move using wind power and stored up wind energy when necessary. They use sails to initially capture the energy of the wind and use it for movement. Wings are used to power pumps that can pump air into plastic bottles. When these bottles are filled, the air inside can be released and used to move the Strandbeests when there is no wind. The complex Strandbeests also include reflexes to react to certain scenarios. For example, if a Strandbeest detects water, it will turn and go towards high ground or, if it detects high winds indicating an approaching storm, it will stop and anchor itself. Jansen refers to the Strandbeests as animals due to their ability to move on their own and he tours the world showcasing his creations.

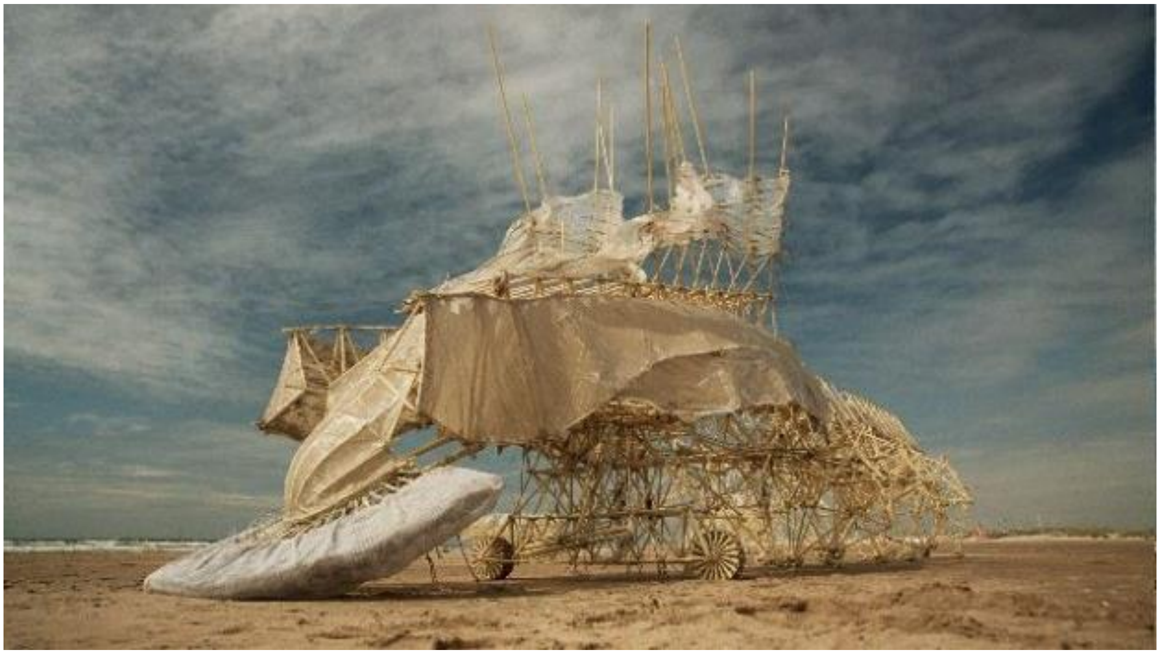


Figure 3. Strandbeest creation that will walk across a beach using only wind power

2.2.4 Kitano

Kitano[6] is a concept yacht that uses a kite as the primary means of propulsion with dual water jets used as secondary propulsion during calm winds. Using a kite as propulsion instead of a sail has advantages that include being able to capture more constant wind speeds at higher altitudes and generating more forward force using less surface area. This means that even a light breeze will provide enough force to propel the yacht to planning speed. The position of the kite can be changed which can be used to counter the force of heeling and the yacht can sail without tilting. This makes for a smoother ride and lessens the chance of the passengers experiencing seasickness. Electric winches are used to control the position of the kite. The autopilot controls the winches to compensate for unexpected changes in wind speed and direction. The kite can also be steered manually by changing the tension in the lines connected to the kite. The position of the hauling point of the kite on the yacht can be changed in the longitudinal and transverse directions depending on the direction of the course. The kite will have helium filled bladders to help support the kite during launch and to keep the profile. As of now, it is just a concept however that will most likely change in the future as sustainable energy becomes more prominent.

2.3 Goal Statement/Objectives

There are two end goals to this project. The first goal is to demonstrate that the scaled power generating device will be able to turn on a light bulb. In an ideal world, a kite would be used as the mechanical input, however if that is not possible a hand pulling on the kite string can be used. The main challenge in doing this is to get the kite to oscillate to generate power via a pogo solenoid coil. The second goal of this project is to harness the moisture in the air at altitude and deliver it to an aquifer on the ground. For this aspect of the project, a proof of concept with detailed drawings is all that is needed. There is also a desire to come up with a mechanism that will launch the kite when the winds are strong enough and gracefully lower the kite when the winds die down.

2.4 Constraints

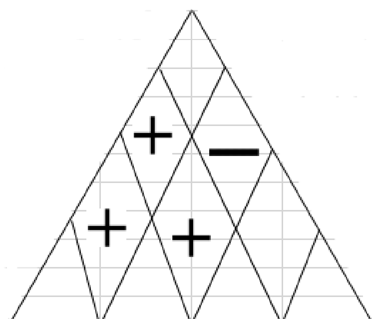
When designing the power generating subsystem of a kite power generator it is important to know what limitations there are for a specific design. For the project that will be executed the power generation will be optimized for altitudes between 500 and 1500 feet. The kite generator will also be optimized for a specific region, the Islands of Greece. The altitude constraint along with the geographic constraint will allow for the design of a kite that a certain nominal wind speed for that region and altitude. The kite must also deliver AC power to the grid so that it is generating usable electricity. The parts that are used in the assembly of the kite power generator must be off the self-products to allow for efficient assembly of the system with no manufacturing of custom parts involved. It is important to operate within these constraints to ensure that the concept designs are on target and will achieve the desired function.

3. Methodology

To meet the goals of the project, working together and scheduling out tasks ahead of time plays an important part and ensures that things get done. Every team member is assigned with a position and tasks to complete based on their strengths in the field in order to complete the project as efficiently as possible.

3.1 HOQ

While the team was still the background research phase of the project, a house of quality (HOQ) was generated to narrow the focus of the project and allow for the more time to be spent on important engineering characteristics and customer requirements. The HOQ can be seen in Figure 4, showing all engineering characteristics and customer requirements. Each category is also scored. The higher scored engineering characteristics and customer requirements are the ones that are more important while the lower scored items are considered to be less important.



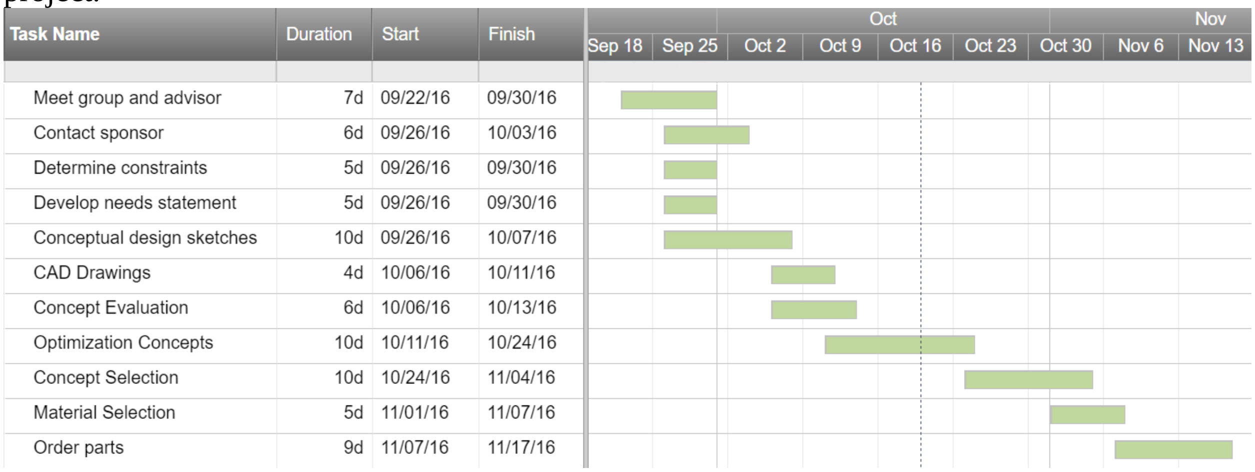
		Engineering Characteristics				ComA		
Customer Requirement	CI	Voltage and Timing for Power Grid	Spring/ Hydraulic Force	Wind Speed Recognition	X Liters of Water Collected	KITEnrg	KiteGen	Planned
Water Collector	1	0	1	1	3	0	0	3
Launching Mechanism	2	2	0	3	1	1	1	3
Budget of $2,000	3	2	2	2	1	2	1	3
Power Generation	5	3	3	2	0	3	3	3
Convert DC to AC Power	4	3	1	0	0	3	3	3
Score		37	26	23	8			
Relative Weight		0.39	0.28	0.24	0.09			
Rank		1	2	3	4			

Figure 4. HOQ to show initial customer requirements and engineering characteristics

Through weekly meetings with our sponsor and adviser, the customer requirements/scope are constantly evolving since it is still early on. This means that the HOQ is constantly evolving and new evaluations are done week to week. For this reason, instead of recreating a HOQ every week, and list of customer requirements and goals is kept and those goals are ranked each week. The current list is as follows from most important to least important: Power Generation, Kite Control, Cost, Ease of Deployment, Mobility, and Maintenance. These criterion were used in coming up with good concept ideas.

3.2 Scheduling

Figure 5 The schedule for the project is presented in the form of a Gantt chart where it clearly shows the name of each task, the duration of the completion, and the beginning and end date, excluding ME deliverables since they are fixed assignments that will be competed alongside the project.



Task Name	Duration	Start	Finish
Meet group and advisor	7d	09/22/16	09/30/16
Contact sponsor	6d	09/26/16	10/03/16
Determine constraints	5d	09/26/16	09/30/16
Develop needs statement	5d	09/26/16	09/30/16
Conceptual design sketches	10d	09/26/16	10/07/16
CAD Drawings	4d	10/06/16	10/11/16
Concept Evaluation	6d	10/06/16	10/13/16
Optimization Concepts	10d	10/11/16	10/24/16
Concept Selection	10d	10/24/16	11/04/16
Material Selection	5d	11/01/16	11/07/16
Order parts	9d	11/07/16	11/17/16

Figure 5. Gantt chart showing future plans for the fall semester

In reference to the Gantt chart, the first task of the team was to meet its members and set up a meeting with the advisor. Background research shortly followed on various companies with a similar a goal statement as the kite-powered generator to gain insight on how to proceed with determining the constraints and the needs statement of the project. Then, the team proceeded to develop concept drawings that satisfied all the needs of the project but also worked around the constraints. The three designs were generated using CAD software and compared using a Pugh matrix based on the five main design considerations: maximum power generation, kite control, cost, ease of deployment, and maintenance. The team is currently in the stage of concept optimization which consists of the analysis of different concepts that could be applied to the final concept to permit maximum power generation since that is the main goal. The team also meets every week with the sponsor and advisor to stay on track with the tasks needed to complete the project. The team actively meets every week to work on tasks together, distribute work evenly, and discuss project details to ensure the team stays on track with the Gantt chart.

3.3 Resource Allocation

Every person on the team holds a specific responsibility and is assigned an individual assignment each time a task needs to be completed in order to complete said task on time. The tasks are divided evenly among the team members as shown in Table 1, including ME deliverables.

Table 1. Showing how the work load has and will be distributed

Task	Team Member(s) Responsible
Background Research: Kite Power Generation	Denitsa, Zachary
HOQ	Andrew, Matthew, Denitsa, Zachary
Project Planning: Gantt Chart	Andrew, Denitsa
Needs Statement/ Goal Statement	Andrew, Matthew
Code of Conduct	Andrew, Matthew, Denitsa, Zachary
Concept Generation	Andrew, Matthew, Denitsa, Zachary
CAD Concept Drawings	Matthew, Zachary
Concept Evaluation: Pugh Matrix	Andrew, Denitsa, Zachary, Matthew
Concept Optimization	Andrew, Denitsa, Zachary, Matthew
Midterm 1 Report	Andrew, Denitsa, Zachary, Matthew

The table excludes tasks such as team meetings, communications with the sponsor and advisor, and any type of correspondence. Andrew Colangelo handles the communication as Team Leader. He holds the responsibility of delegating tasks based on the team's strengths while making sure every member gets their assigned tasks completed in time. He also takes the lead in future planning, organizing, and setting up the weekly meetings with the sponsor as well as the team meetings.

Zachary Ezzo is the team's Lead ME, who manages the mechanical design aspect of the project. He holds the responsibility of being well informed of the design specifications and leading the team through the design process. He presents design options to the team that fall under the project's design considerations and are within the constraints.

Denitsa Kurteva is the team's Financial Advisor, who holds the responsibility of managing the project budget and performing costs analyses on the designs chosen for cost optimization. She holds a record of all credits and debits of the project's account as well as budget adjustments.

Matthew Hedine is the team's Lead CAD Design who oversees all computer modeling. He holds the responsibility and computer modeling the concepts generated and delegating design work, as well as generating design drawings.

4. Concept Generation

In the creation of the design concepts, the major considerations taken included maximum power generation, kite control, maneuverability, ease of deployment and maintenance. A pogo solenoid base was used on each concept design to mock the already patented idea from our teams sponsor Jeff Phipps.

4.1 Concept Idea 1

To gain control of the kite and generate the maximum possible power from the wind speeds, it is important to consider the angle of attack and its direct correlation with the frequency of the kite's oscillation. In the first concept design generation, four strings are used attached to the kite on one end and to the magnet on the other end. To optimize the oscillation of the kite to take account varying wind speeds, mechanical winches are added onto each of the four strings that allow for the user to gain control of the kite's angle of attack. One of the benefits of this design is that the winches are close to the ground which allows for easy user access when in operation.

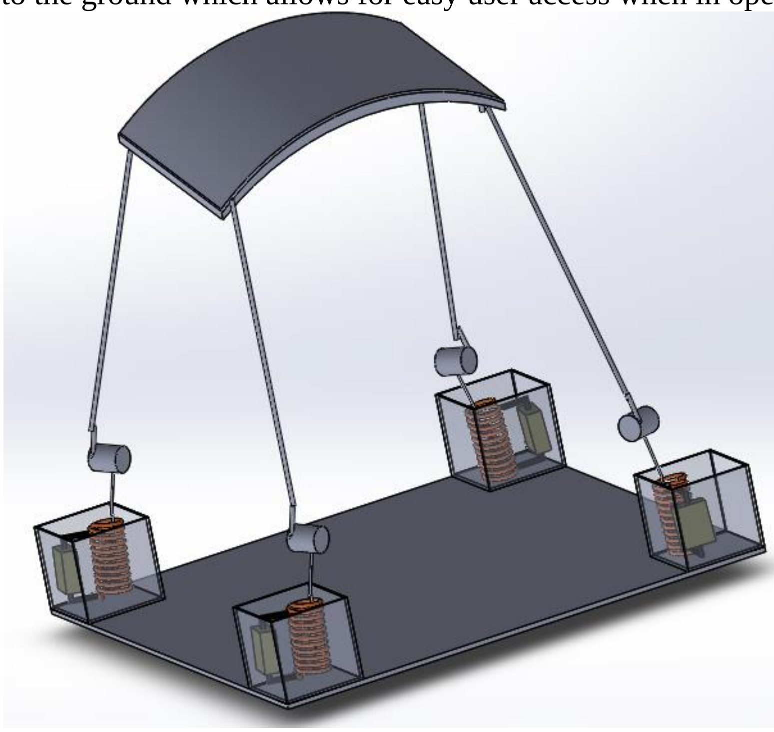


Figure 6. Four-string kite concept idea

Figure 6 Inside the power generation box, the string is attached to the magnet which moves back and forth inside the coil with the kite's oscillation. Thus, the higher the oscillations, the quicker the magnet moves inside the coil and generates power via electromagnetic induction. The AC current that is generated will then go through a rheostat which will convert it into DC. This current will then go through an inverter which will convert the electricity back into AC and allow the electricity to be distributed to the grid. The magnet is attached to a spring that would allow the magnet to oscillate back and forth. As the kite oscillates and pulls the magnet away from the ground, the spring brings it back to keep it inside the area of the coil and can generate a voltage.

The stiffness of the spring will depend on the length of the coil since the magnet must stay inside the coil for power to be generated.
This design is beneficial in that it allows the user to easily gain control of the kite from the winches that are close to the ground. This would allow full control of the oscillation of the kite which in turn would in theory generate the maximum power possible. However, while four strings allow for maximum control of the kite, it is important to consider the energy loss from using multiple strings. The vibrations in the system from the kite's oscillation would be distributed over four strings, thus not providing enough tension in each string to generate maximum power.

4.2 Concept Idea 2

The two-string kite design is a condensed version of the four-string kite design. This design relies on two kite tethers attached to either side of the kite and connected to the ground. The advantage of having two less kite tethers is that more tension is created in the remaining two tethers. The lift force due to the wind load is now dispersed to only two tethers rather than four. This allows for a higher spring tension which in effect will cause more oscillation. The weight of the kite will also be much less, allowing the kite to easily remain in the air when wind speeds begin to diminish. Having two tethers on either side of the kite still allows for moderate control of the kite. This design will not allow for full control of the kite as does the four-string kite, however, the kite's angle of attack would still be able to be altered with minimal energy input. Also, with the two-string kite design, the mechanical components will be on the ground making it easy for repair and maintenance when necessary. Containing the mechanical components either in the housing or near the ground helps to avoid the issues caused from the natural elements.

Figure 7. Two String kite concept idea

4.3 Concept Idea 3

The in-air winch design differs significantly from the previous two designs. This design will incorporate only one kite tether attached to the ground to generate power. Utilizing only one tether maximizes the tension resulting in greater oscillation. This design uses a single housing to generate power. This is beneficial in that there is less surface area needed to deploy the kite as well as less hardware that can break down. However, if the housing does break down, the kite will then cease to generate power until the housing is repaired.

The in air winch design, as it states, has the winch in the air near the kite, rather than near the ground or housing. Having the winch connected in the air near the kite creates a focus on the single tether coming down to the housing. This prevents any tangling of tethers as the wind loads fluctuate as well as a smaller of a chance of interference to the surrounding environment.

Figure 8. In-Air winch concept idea

4.4 Demonstration Concept Idea

The design for the demonstration model is a simplistic design as compared to the overall design considerations. The demonstration will focus on the power generation aspect, therefore a kite is not necessary. For this design, the demonstration entails a force on a string that will pull the magnet through the solenoid as well as return it to the previous position. This demonstration model will utilize a stationary bike with a three bar linkage to allow the magnet to follow a fixed path through the solenoid. The mechanical input of the demonstration model, the stationary bike for the figure below, can be altered based on the sponsor's preferences. Other options for the mechanical input could include weights attached to pulleys being dropped, or a string with a handle with which a person would exert a force on the string pulling on the magnet. Per the sponsors request, the demonstration model is to be of a very simple design to demonstrate the power generation due to oscillation of a magnet through a solenoid.

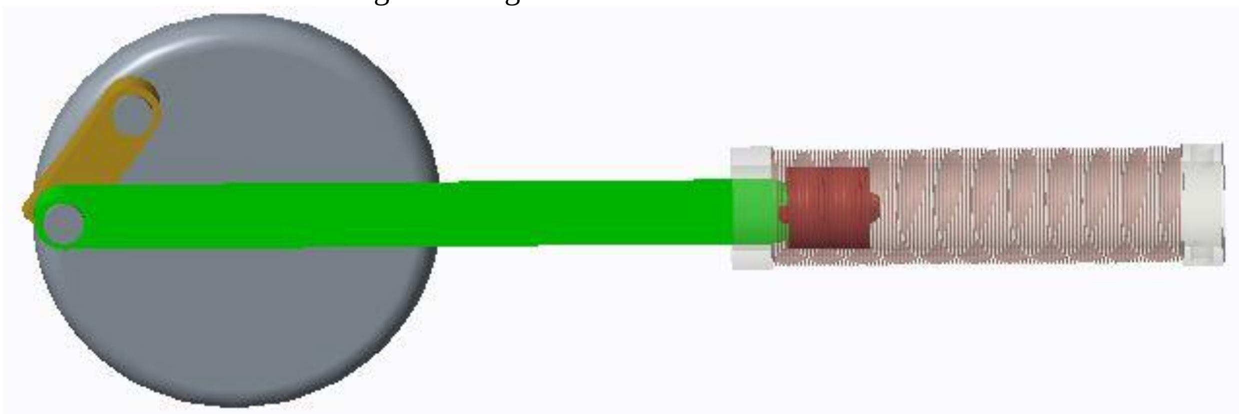


Figure 9. Demonstration Model Concept with Stationary Bike

5. Conclusion

Through the background research and deliberation, the concept ideas were presented as potential ideas to use going forward. In an effort to narrow the focus of the project a single design was chosen using the Pugh Matrix seen in Table 2. The design considerations are different from those found in the HOQ because after meeting with the sponsor of the project, he wanted to change the scope of the project to be more on the power generating device rather than the kite design itself.

Table 2. Pugh Matrix used to compare concept ideas

Criterion	Baseline	Weight	4-String Kite	2-String Kite	In-Air Winch
Power Generation	0	6	0	0	1
Kite Control	0	5	1	0	-1
Ease of Deployment	0	3	-1	1	0
Mobility	0	2	-1	0	1
Maintenance	0	1	-1	1	-1
Cost	0	4	-1	0	1
Sum	0	-	-5	4	6

The decision was made to move forward with concept idea 3 which is the in-air winch design. This decision was partially based on the Pugh Matrix and partially based on discussion with the sponsor and the advisor to the project.

The next step will be to optimize this design for the preferred geographical region which was laid out in the constraints. A method of oscillating the kite with little to no power input and a method of keeping the kite in the air at lower wind speeds has yet to be determined.

The final design for the demonstration model also must be determined by the end of the semester so that parts can be ordered and the spring semester can be used to assemble and test the model. At the time of the midterm 1 presentation, it was thought that the mechanical input for the demonstration model would be a stationary bike, however the sponsor expressed that he does not want this to happen anymore so it will be a goal to demonstrate the generation of usable electricity by some other means.

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