Design for Manufacturing, Reliability, and Economics

Team 9

Development of Power Converting Sub-System of Kite Power Generator

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1. Design for Manufacturing

Designing a product for manufacturability involves assuring that the product has the best cost, quality, and reliability all while maximizing safety and customer satisfaction. Before generating parts for the demonstration model, the concept model needed to be designed and scaled down. The amount the demonstration model was scaled down by was based on how much power was needed to be generated in order to power a 40W light bulb and how much force the traction kite generated at the expected wind speeds.

The first step in assembling our demonstration model was getting the base housing and solenoid housing machined. All the other components were off the shelf products. Assembly of the system started with attaching the three springs to the inside roof of the housing using an adhesive and centering them around the hole in the housing. After that, the magnet was placed at the center of the end of the first spring. The middle kite string was run through the hole in the roof of the base housing and through the springs to the magnet where it is tied on. The copper wire was then wrapped around the solenoid housing which was then placed around the springs and magnet and attached to the roof of the base housing using adhesive. The excess copper wire hanging off the solenoid is used to connect to a device to store and transmit the electricity. The roof of the base housing was then attached to the walls using screws. The solenoid and springs that were attached to the inside of the roof housing had to be guided into place to make sure they didn't come into contact with the walls of the base housing once the roof was screwed into place. The last part of the assembly was attaching the magnet string to the kite. In order to do that, two lines were attached at the junction of the control strings on the sides of the kite. These two strings met at a clip in the middle. The string that was tied to the magnet was then brought up and tied to the clip. This length of string was made to be slightly longer than the two existing strings that are used for controlling the kite. This was done so the kite could be controlled by the user at a normal height. The exploded view of the demonstration model can be found in the figure below.

The design process for the demonstration model did not take much time do complete. This is because it is a scaled down version of the concept model. The base housing was scaled down and designed so that one of the sides is open for viewing purposes. It was made out of aluminum because it is a non-magnetic material. The base plate was extended outwards to provide more stability during operation. The solenoid housing was designed to fit inside to the top of the base housing. It was selected to be made out of plastic because it is non-magnetic and able to be used for 3-D printing. A slot running the length of the solenoid housing was included in the designed so that the inner components could be viewed during use. The materials were selected to be non-magnetic so that the magnetic field would not be effected.

The overall assembly time of the demonstration model took slightly longer than was expected. The base housing took as much time as expected to be machined and put together but the solenoid housing took slightly longer than expected. This is because there was some debate whether or not to have the part machined or 3-D printed and also what material it should be made out of. Ordering the off the shelf parts took as much time as was expected, however, the springs needed to be reordered due to trial runs yielding less force generated from the kite than was expected.

There are not too many components on the design of the demonstration model that are able to be simplified any further. The base model housing can be simplified to have the roof welded to the top so that it is all one piece and doesn't require screws to be attached. The solenoid housing can be made without including the slot because viewing the inner components in not necessary. The cost of the solenoid housing can be decreased by selecting a cheaper method of constructing it instead of 3-D printing. Figure 1 shows the exploded view of the model with each crucial component labeled.

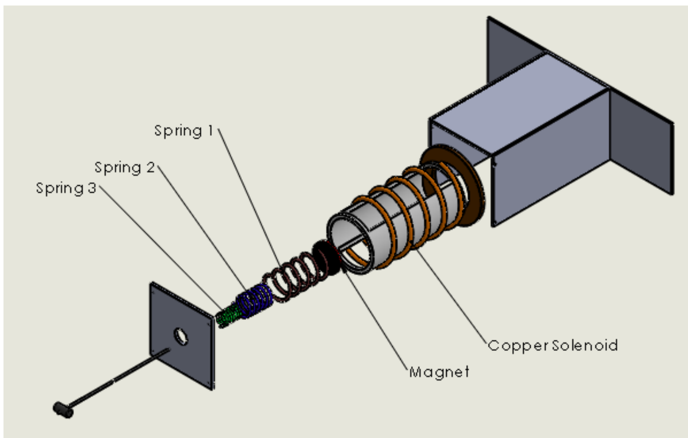

Figure 1. Exploded view of kite powered generator with crucial components labeled

2. Design for Reliability

A very important aspect of the design of this system is the reliability of the system as a whole and as well as its individual components. It is critical that the system function successfully without failing in order to minimize downtime and maximize usage. In terms of reliability, nothing went wrong during the multiple test runs that were performed with the demonstration model. However, assuming that the conditions are optimal for testing, the demonstration model should be able to perform many test runs before any issues arise. Some of these issues could include, but are not limited to, the adhesive holding the springs to the roof of the base housing possibly coming undone or the kite string could possibly fray or even break due to friction against the aluminum base housing. Also, the kite itself could tear due to the experience of repeated tension forces. Other issues with the system could include the copper wire coming unwrapped off of the solenoid housing and the base housing disconnecting from its grounds and being lifted up due to the forces of the kite in a strong gust of wind. It is impossible to tell how long it will take for these issues to arise, it could take 100 test runs or 10,000 but they will eventually arise and need to be addressed.

The main reliability concern would be the kite or kite string breaking. This would be a major failure which would stop all testing and would require a completely new kite and/or string to be ordered to continue operation. The other major concern would be the base housing becoming ungrounded and lifted up because this would be a huge safety hazard. These issues can be addressed by performing regular inspections to make sure that there is no concerning wear and tear on the kite or the kite string and checking to make sure that everything is safe and secure before undergoing operation of the system. Regular inspections would also be effective at preventing the other issues that could arise. Table 1 shows the FMEA that was done for the kite powered generator system.

Table 1. FMEA for demonstration model of kite powered generator

Process Step/Input	Potential Failure Mode	Potential Failure Effects	SEVERITY (1 - 10)	Potential Causes	OCCURRENCE (1 - 10)	Current Controls	DETECTION (1 - 10)	RPN	Action Recommended	Resp.
What is the process step or feature under investigation?	In what ways could the step or feature go wrong?	What is the impact on the customer if this failure is not prevented or corrected?		What causes the step or feature to go wrong? (how could it occur?)		What controls exist that either prevent or detect the failure?			What are the recommended actions for reducing the cause?	Who is responsible for making sure the actions are completed?
Kite catches strong wind	Kite string snaps	Kite falls to the ground	9	Knots on 3rd string aren't tied correctly	2	Visual Inspection	4	72	Replace kite string/ retie knots	senior design team
Tether pulls hard on springs	housing unglues/ top breaks	electricity stops being generated	8	Housing not glued correctly or strong winds	3	Visual Inspection	4	96	Glue properly/ use durable material	senior design team
Flying the kite in strong wind conditions	Housing lifts up from the ground	possible injury/ model breaks	9	housing not grounded/ strong winds	2	Visual Inspection / manually holding it down	5	90	Enough testing and practice using the housing	senior design team

3. Design for Economics

The entire demonstration model costs roughly $887 altogether. The power generation portion of the project cost roughly $267 and that includes the magnet, springs, and the electrical copper coil. The prototype was built out of aluminum and was screwed together, which cost about $179. Kites were purchased to examine which kite will generate more lift and thus generate more power, which collectively were $270. Additionally, a motor was purchased at a price of $100 to mimic the kite motion in the event that the kite does not produce enough power for a 40 W lightbulb. The budget breakdown is represented in Figure 2.

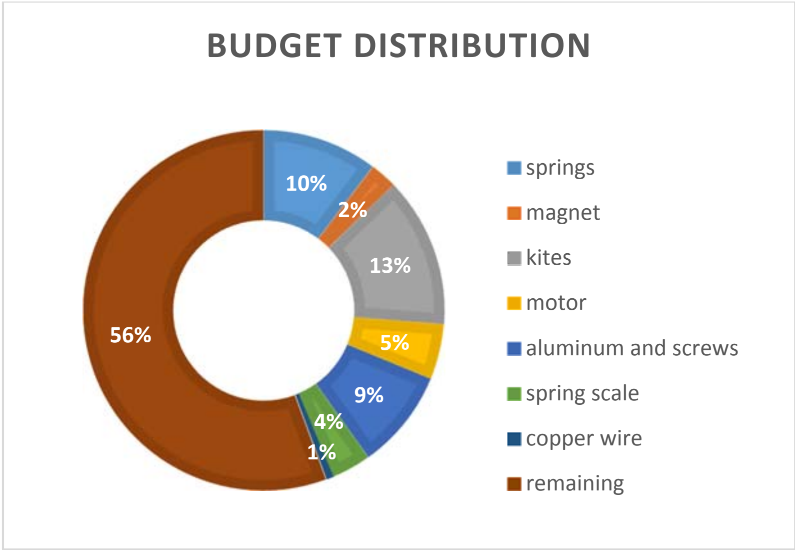

Figure 2. Pie chart representation of budget breakdown

A couple of companies who have also harnessed the wind via kites are Kiteship, Skysails, and Kitano. Kiteship is a company that utilizes sail-kites on freight commercial ships as an aid to pull the ships in their journey across the ocean. The cost of one of these products is unknown but its savings are roughly $400,000 per year. 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.

Skysails is also a 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. The cost for one of these products is also unknown. Another company similar to the kite power generator is Kitano. It 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. The kite can also be steered manually by changing the tension in the lines connected to the kite, in the same way the kite is steered using the demonstration model in our project. This is only a concept thus there are no costs associated with the model to use for comparison.