Team 9: Development of Power Converting Sub-System of Kite Power Generator

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Presentation Overview

- Project Scope/Goals
- Demonstration Model
- Concept Model
- Challenges Encountered
- Planned Methodology/Future Plans
- Summary

The Problem at Hand

- Worlds energy consumption expected to increase by 48% by the year 2040[1]
  - Wind turbine
  - Solar energy
  - Nuclear energy
- Optimize for Greek Islands
  - Wind speeds of around 20mph

Design and build the power generating system of a kite power generator, and scale for a 100kW concept kite.

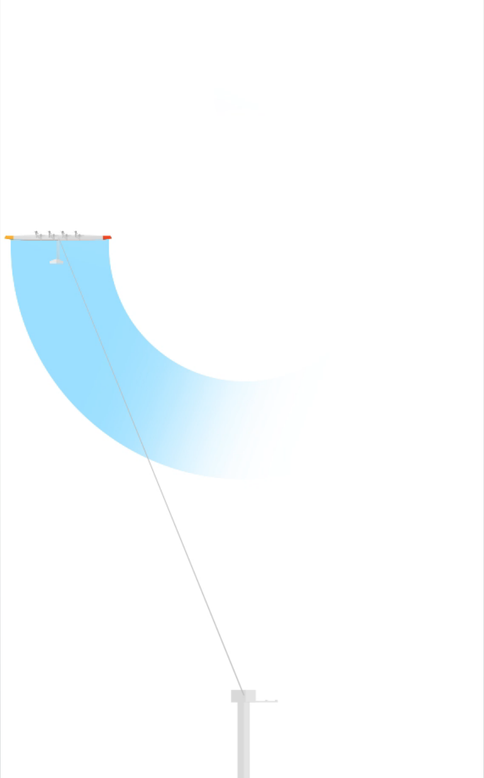
Constraints

- Altitude between 500 and 1500 feet
- Must deliver AC power to grid
- Limited to off the shelf products
- Optimized for Greek Islands

Figure 1. Picture showing mountainous Greek islands

Project Goals

- Demonstrate that magnet in electrical coil will generate usable electricity
  - Use a kite to oscillate magnet
  - Varying tension in line/spring
  - Power a lightbulb
- Concept for a method for optimization of energy output based on wind speeds
  - Scale for a 100kW kite
- Determine feasibility for mass power generation



Makani energy “kite”

General Schematic

Kite flies in unsteady wind conditions

↓

String and spring are tensioned → Magnet moves through coil

Hooke's Law $F = -k\Delta x$

↓

Spring pulls back on magnet → Magnet moves back through coil

↓

Faraday's Law

$$V = -N * \frac{\Delta(BA)}{\Delta t}$$

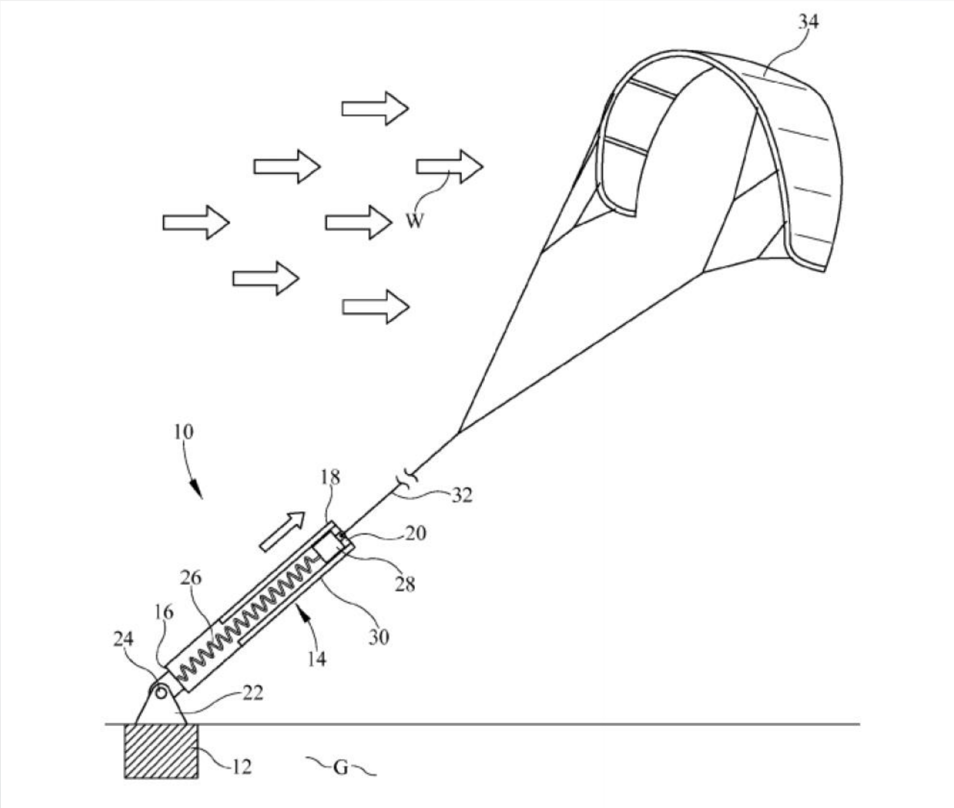


Figure 2. Jeff Phipps patent of power generating kite (diagram not to scale)[3]

Figure 3. Figure-8 kite path

Demo Model

- Method of varying effective spring coefficients
  - Concentric springs
- Determined optimal conditions for necessary power generation
  - Magnet speed/strength
  - Number of coils
- Magnet of 1.32T strength moving at a speed of 50 wraps/sec to power a 40W light bulb

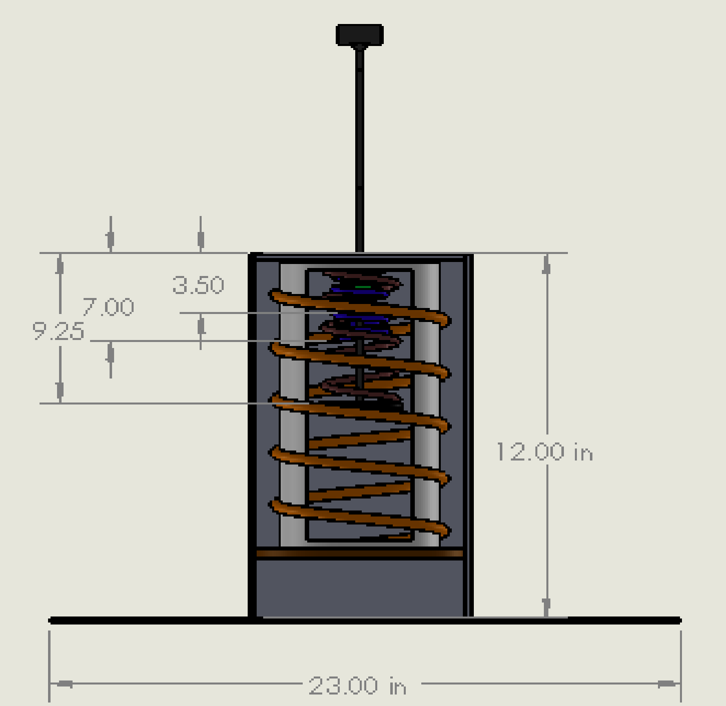


Figure 4. Concept for kite stabilization/control

Kite Selection

- Tested kites for maneuverability
- Traction and Stunt kite
  - Traction kite
    - More lift
    - Higher control
    - Slower movements
  - Stunt Kite
    - Less lift
    - Faster maneuvers
    - Less stable
  - Force output via spring scale
    - 3-5 lbs on straight path, 10-15 lbs on curves

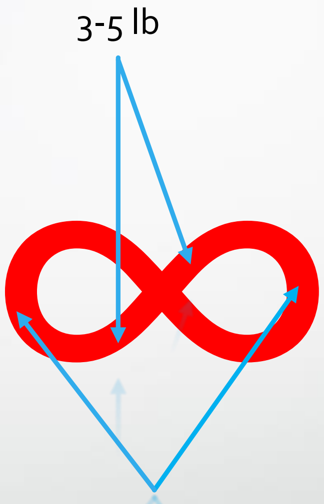


Figure 5. Path of kite

Figure 5. Traction kite that was tested

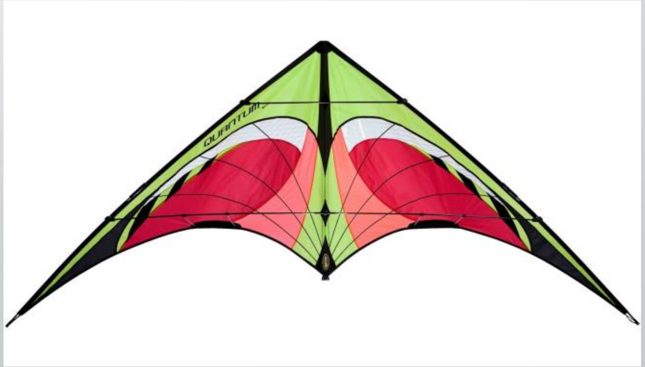


Figure 6. Stunt kite that was tested

Demo Testing

- Two lines tied from junction of all control stings
  - One on left, one on right
- Strings meet at quick clip in middle
- Single line down to power generator
- Initial voltage generation measurements
  - Max voltage was 20mV
  - 3 orders of magnitude less than expected

Figure 7. Diagram showing how 3rd string was attached

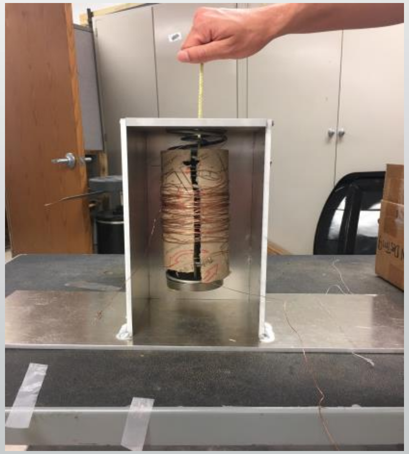


Figure 8. Demonstration model preliminary test setup

Andrew Colangelo

Proposed Improvements

- Acrylic Housing
  - Does not interact with magnetic field
  - Thinner sidewalls
  - Allows for stationary coil
- Tighter wire wraps and more of them
- Lower coefficient springs
  - Allows for faster and more compression

Table 1. Gantt Chart for Spring semester

	Springs	Length (in)	Stiffness (lbs/in)	Outer D (in)	Inner D (in)	Solid Height (in)
Old	1	9.00	13.00	3.00	2.62	1.54
	2	6.88	9.00	1.50	1.25	1.88
	3	3.50	153	1.00	0.68	2.11
New	1	9.25	2.20	2.25	2.01	1.68
	2	7.00	1.70	1.55	1.37	1.61
	3	3.50	153	1.00	0.68	2.11

Lift Calculations/Kite Strings

- 35 mph headwind from 20mph wind at sea level
  - Lift force at 5 degrees angle of attack is 15lbf
  - Lift force at 15 degrees angle of attack is 45lbf
- 1/4" Diameter Nylon String
  - Breaking Strength: 1805 lbf
  - Weight: 0.016 lb/ft
  - Mold and mildew resistant
  - Great strength to weight ratio
- String deflection was estimated to be ~0.5in
  - Negligible potential energy lost to string

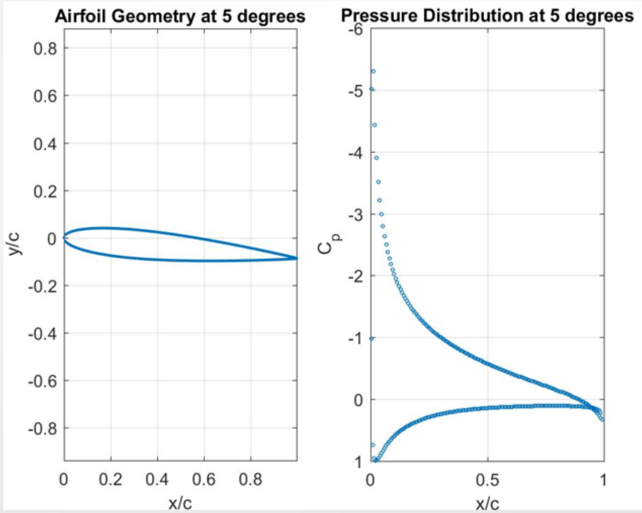


Figure 9. Pressure distribution at 5 degrees

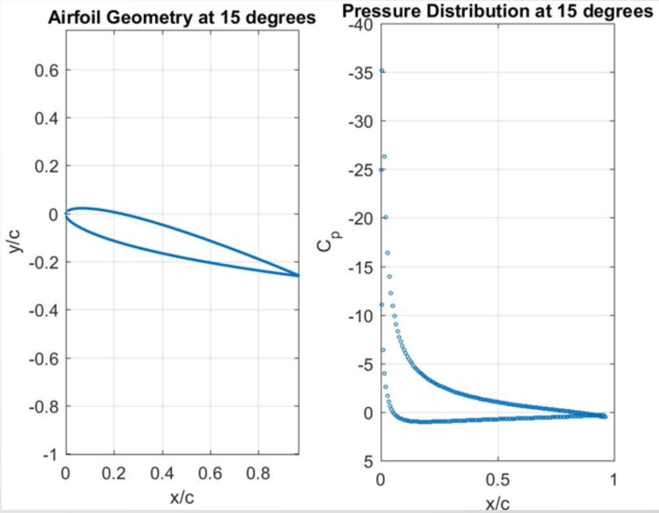


Figure 10. Pressure distribution at 15 degrees

Mimicking Kite Motion

- Designed concepts for kite oscillation if kite cannot be correctly maneuvered
  - Motor will be used to mimic the tension in the line
- Allows for optimization of desired kite frequency
- Kite force can be varied by winding string around shaft
  - Compresses spring

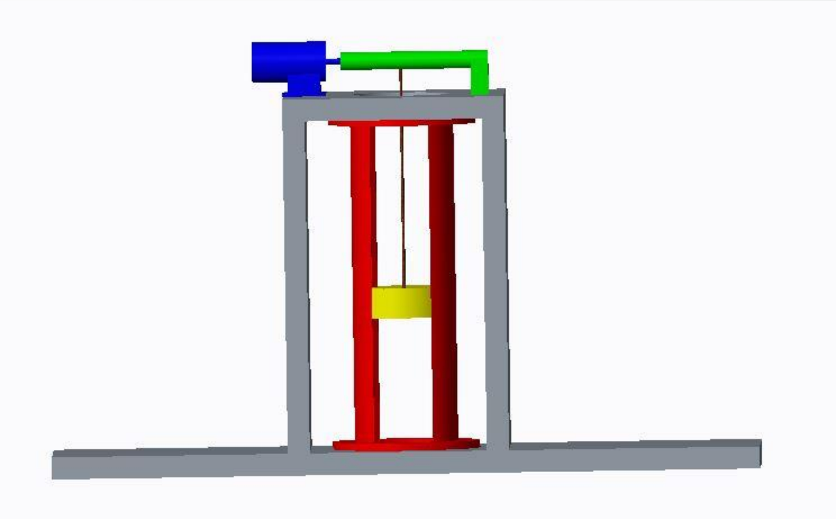


Figure 11. Motor to be used for kite motion mimicking

Motor Selection

- High Torque motor
- Will be programed to achieve different compression rates
- Different setups for different compression lengths

Table 3. Motor Specifications

Motor Specs	
Continuous run torque	21 in-oz
Type	12V DC
Shaft Diameter	0.250"
Shaft Length	1"

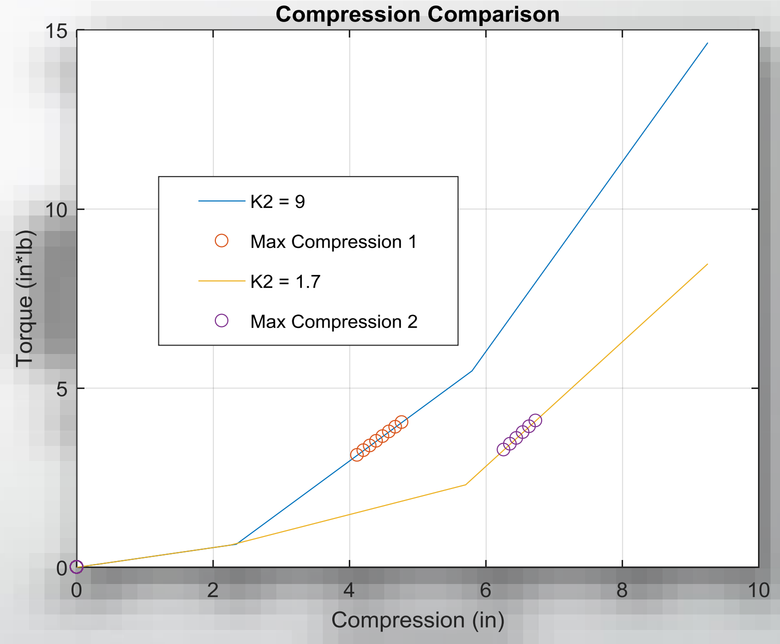


Figure 12. Compression of springs using selected motor

Challenges Encountered

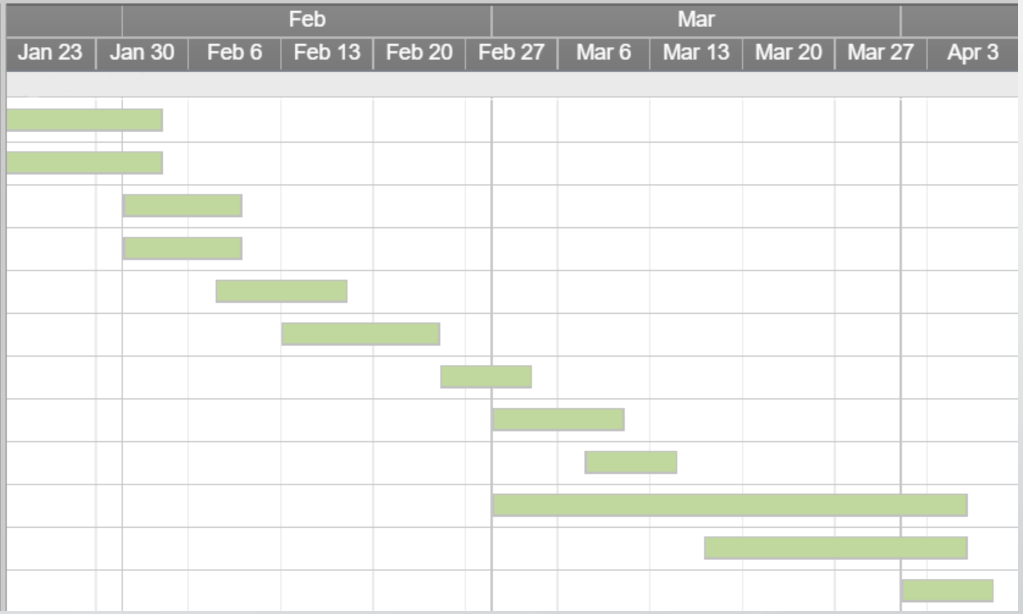
- Controlling demonstration model kite
  - Finding suitable wind to maintain steady flight path
- Attaching string to housing without loss in maneuverability and deforming kite
- Narrowing down the scope
- Much lower power generation than expected

Figure 13. Icing on an airfoil

Planned Methodology

Table 2. Gantt Chart for Spring semester

Task Name	Duration	Start	Finish
Order kites	10d	01/23/17	02/03/17
Finalize ground plate and housing designs	10d	01/23/17	02/03/17
Machine grounding plate	7d	02/01/17	02/09/17
3D print springs housing	7d	02/01/17	02/09/17
Test kites	8d	02/08/17	02/17/17
Kite control concept generation	10d	02/13/17	02/24/17
Kite control concept selection	6d	02/25/17	03/03/17
Kite performance optimization	8d	03/01/17	03/10/17
Concept kite material selection	5d	03/08/17	03/14/17
Demonstration model testing	26d	03/01/17	04/05/17
Refine demonstration model	14d	03/17/17	04/05/17
Finalize 100kw scale model concept	6d	04/01/17	04/07/17



- Weekly meetings with sponsor/faculty advisor
- Bi-weekly meetings with team to tackle problems and catch up on individual tasks

Future Plans

- Machine acrylic housing for copper coil
- Test demonstration model with kite attached
- Determine where losses are in power generator
- Program motor to simulate kite motion at varying wind speeds
- Scale up for 100kW of power
  - Is this feasible for commercial purposes?

Table 3. Budget breakdown

Items	Cost (USD)
3 springs	129.44
Magnet	48.26
2 kites	270.27
Al sheet	162.93
Copper ire	13.2
Spring scale	71.13
Screws	16
New springs	76.69
Acrylic rod	351
DC motor	99.53
TOTAL:	1,238.45

Summary

Design and build the power generating system of a kite power generator, and scale for a 100kW concept kite.

- Demonstration Model has been assembled and preliminary test have been conducted
  - Induced voltage 3 orders of magnitude lower than expected
- Lift and elastic losses for concept kite
  - Determines springs needed for concept model
- Motor will be used to simulate kite oscillation and allow for optimal frequency
  - Feasibility of reaching optimal frequency

References

[1] http://www.eia.gov/todayinenergy/detail.php?id=26212

[2] http://www.climatechangepost.com/greece/fresh-water-resources/

[3] https://www.uspto.gov/patents-application-process/search-patents

[4] http://www.conserve-energy-future.com/Disadvantages_SolarEnergy.php

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[6] http://www.kitenergy.net/technology-2/key-points/

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[8] https://www.ted.com/talks/saul_griffith_on_kites_as_the_future_of_renewable_energy?language=en

Questions?