Non-Point Source Polluting Lawn Mower

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ABSTRACT

Lawn mowers and other lawn care equipment are some of the biggest causes of pollution on the market. This project strives to find a suitable power alternative for a lawn mower which will have satisfactory performance without emitting the large amount of pollution produced by a gas driven mower. A motor has been selected, along with a suitable power source, but work still remains to complete the project.

INTRODUCTION

In the present era, with petroleum usage skyrocketing, global warming has become a major crisis that needs to be dealt with. Petroleum is being used as the major power source for many applications such as automobiles, heating, and the study of this project, lawn care.

“Some older lawn mowers are bigger polluters than the family car,” said James M. Lents, executive officer of Air Quality Management District in Orange County California. “A dirty mower operated for 20 hours a year produces the same amount of smog-forming volatile organic compound pollution as a 1996 passenger car driven for 26,000 miles -- more than most people drive in a year,” Lents said.[1] With this being the case, it can be seen that in order to reduce pollution emissions, an alternative needs to be found to power lawn mowers. Whether this is done by using a new technology such as a fuel cell, or by utilizing battery or solar power, this project aims to cut the point-source pollution output by the use of these machines.

OBJECTIVES

Currently, there are models of lawn mowers that are on the commercial market which do not require the use of gasoline for a power source. Most of these are battery powered and do not have enough power to cut more than a quarter of an acre. For a typical Maine resident, a mower that will only cut a quarter of an acre is not sufficient. The full scope of this project seeks to construct a non-polluting lawn mower will mow at least an acre of land before running out of power.

The objectives we are striving to meet are:

- Substantial reduction in pollution emissions
- Suitable power supply to cut 1 acre of land or more
- Relatively inexpensive

SEMESTER RESULTS

POWER REQUIREMENT

The first thing we needed to determine to create a suitable non-polluting lawn mower was the power requirement needed to cut the average lawn. In order to do this, we performed a test with the stock system. Originally, we were unable to get the lawn mower to run. We dismantled the lawn and rewired it with both a voltmeter and an ammeter to check the voltage and current running to the electric motor. We found that there is an initial spike at start up. This spike hit 100 amps before declining. With the mower running without cutting any grass, we found that the amperage needed to spin the blade was 10 amps. Since the stock mower runs on two twelve volt lead acid batteries, this gave us a power requirement without a load of 240 watts. When we took the mower outside, we found that the max amperage needed to run the mower through thick, wet grass was 70 amps. This gave us a max power of 1680 watts.

POWER SOURCE

When seeking to find a suitable power replacement to a gas powered combustion engine to run a mower, we found four possible solutions: a fuel cell, solar power, use of biofuel instead of gasoline, or battery power. There were benefits and disadvantages to each alternative. A design matrix of all four selections is shown in Figure 1.

Fuel Cell

Fuel cells are still in the early stages of development. While fuel cells would provide more than enough power to mow an entire lawn, they are still very expensive. Hydrogen is not yet widely available to consumers so this would also present a problem to the average user, along with the addition of a cumbersome storage tank for the gas. There are fuel cells that use other substances such as methanol to produce the hydrogen needed, but that causes the production of pollutants in the reformer.

Solar Power

Solar energy is by far the cleanest and most abundant source of energy that could be used. The problem presented with a solar powered lawn mower is obtaining enough energy to mow a full acre of land. Large panels would be needed to harvest this much energy. Also, to create a suitable mower using solar energy, a battery would also be necessary to retain charge collected by the solar panels.

Power Source	**Weight**	**Fuel Cell**	**Solar**	**Battery**	**Biofuel**
Initial Cost	7	1	2	3	4
Point Source Pollutants	10	3	4	4	1
Power	5	3	1	2	4
Weight	3	1	2	3	4
Mow Time	9	3	1	2	4
Fuel Storage	2	1	3	4	2
Fuel Accessibility	6	1	3	4	2
Total		**90**	**98**	**130**	**122**

Figure 1

Biofuel

Biofuel is created using 85% vegetable oil, and therefore is a renewable source of energy. But while this would reduce emissions, this form of energy does not completely eliminate point-source pollutants from a lawn mower.

Battery

Batteries are widely used and widely available to all. A battery powered dc motor is lighter than a typical combustion engine and much quieter as well. Batteries have been around for a long time and therefore most battery technologies are well developed. One question is whether or not a battery will be able to provide the needed power.

Conclusion

After considering the four alternative power sources we had and utilizing our design matrix, we determined the best power source for that could be used for a lawn mower was an electric battery. Use of a battery will keep the initial cost of the mower down while completely eliminating point-source pollutants and making recharging very easy for consumers.

This choice of course led to the question of which type of battery we should use to power the mower. In order to determine this, we looked into multiple battery chemistries and created a whole other set of design matrices.

BATTERY SELECTION

In order to decide which battery chemistry to use with our lawn mower, we looked at five of the most widely available and widely used battery types. Those types were: nickel-cadmium, nickel-metal-hydride, lithium ion, lithium polymer, and lead acid. Battery selection matrices can be seen in Figures 2 and 3 on the next two pages. Figure 2 is a quantitative matrix while Figure 3 is a qualitative matrix.

Nickel-Cadmium

Nickel-cadmium batteries are fairly cheap and perform well under heavy work loads. It has a long cycle life, but loses performance if it does not have a charge/discharge cycle at least once every month and contains toxic materials.

Nickel-Metal-Hydride

Nickel-metal hydride batteries are a little more expensive than nickel-cadmium. They have an average cycle life but the life is shortened by heavy loads. It is environmentally friendly and needs a charge/discharge cycle every three months to retain performance.

Lithium Ion

Lithium ion batteries have a very high energy density and are very low maintenance. They are very expensive though, and seem to loss performance quickly, even after one year of use.

Lithium Polymer

Lithium polymer batteries are expensive and have a high energy density, although not as high as lithium ion. They have an average cycle life, but have no memory and are environmentally friendly.

Lead Acid

Lead acid batteries are tried and true. They have a lower cycle life then the others, but are the most inexpensive battery, no memory, a high overcharge tolerance, and the lowest self-discharge. They cannot be stored in a discharged condition and a full discharge can rob the battery of some performance.

Battery	Nickel Cadmium	Nickel Metal Hydride	Lithium Ion	Lithium Ion Polymer	Lead Acid
Life Expectancy	1000+ cycles	300 - 500 cycles	300 - 500 cycles	300 - 500 cycles	200 - 300 cycles
Charge Time	1 hour	2 - hours	2 - 4 hours	2 - 4 hours	8 - 16 hours
Cost (7.2 V)	$50	$60	$100	$100	$25 (6V)
Energy Density	45 - 80 Wh/kg	60 - 120 Wh/kg	110 - 160 Wh/kg	100 - 130 Wh/kg	30 - 50 Wh/kg
Toxicity	High	Low	Low	Low	High
Memory	Yes (CD/month)	Yes (CD/3 months)	No	No	No
Overcharge Tolerance	Mild	Low	Very Low	Low	High
Self - Discharge/month	20%	30%	10%	10%	5%
Additional Comments	Prefers High Discharge, Heavy Loads	Heavy Load Shortens Life	Deterioration after 1 year		Can't be stored discharged
	Good performance at low temps	High temp storage shortens life	Store at 40% charge, low temp to prolong life		Full discharge robs battery capacity
	Loses preformance without CD/month				

Figure 2[2,3]

Battery	Weight	Nickel Cadmium	Nickel Metal Hydride	Lithium Ion	Lithium Ion Polymer	Lead Acid
Life Expectancy	9	5	3	3	3	2
Charge Time	7	5	4	4	4	2
Cost (7.2 V)	10	3	2	1	1	5
Energy Density	2	2	3	5	4	1
Toxicity	4	1	3	5	5	1
Memory	8	2	1	5	5	5
Overcharge Tolerance	5	3	2	1	2	5
Self - Discharge/month	3	2	1	4	4	5
Additional Performance	6	5	2	1	1	4
Total		**185**	**126**	**158**	**161**	**192**

Figure 3

<u>Conclusion</u>

After weighting the benefits and disadvantages of each battery chemistry and using our battery selection matrices, we determined that either a nickel-cadmium or lead acid battery would work well with our lawn mower. We have been running on the idea that we would outfit our mower with removable battery packs in order to allow the user to easily replace the battery instead of waiting for the battery to recharge if more energy is needed to complete a lawn. We may choose to make one battery pack with a lead acid while the other is made with nickel-cadmium.

DC MOTOR

When performing the preliminary tests on the stock system we were provided with, we found that the mower had a difficult time handling thick or wet grass. The life of the mower was severely reduced when presented with these mowing conditions. Even the owner of the stock mower told us that the mower ran fine with dry short grass, but could not cut the entire lawn when the conditions were not perfect. After some research to determine what the cause of this was, we found that a typical DC motor runs with a good efficiency when a low torque is applied, but as the torque applied to the system increases, the efficiency of the motor decreases. We concluded that one way to increase the battery life of the mower would be to replace the stock motor with a higher efficiency motor.

Our search led us to a new technology in DC motor design known as a lynch motor. Standard DC motors use stacks of steel laminations which are then wrapped with copper wire and an armature. The lynch motor uses stamped, bent, and coated copper bus bars arranged in a disk as an armature. The disk is then placed within an air gap from permanent neodymium magnets, which are about three times as strong as a ferrite magnet. The result is what's technically known as a wave wound axial gap brushed DC motor. We found multiple versions of this type of motor and created a design matrix of the front runners. This can be seen in Figure 4.

Motor	Power	Price	Voltage	RPM	Weight	Amps	Efficiency
General Electric Model 5BT1344B133	2HP	$200	24V	1050	149	72	82%
Briggs and Stratton ETEK	15HP	$350	12-50V	3500	20.8	180	90%
PERM PMG132	34.3HP	$650	24-72V	3500	24.8	110	88%
PERM PMG080	3.95HP	$465	12-24V	6880	7.5	78	83.20%
AST-789-6 Military Surplus	5HP	$200	28V	4500	53	140	82%
Jack & Heintz AST-639-6	10HP	$360	30V	4000	80	?	?
Leeson AST-9112-01	1.5HP	$240	24V	1800	32	62	?

Figure 4[4,5,6,7]

This matrix led to the conclusion that the best motor for our mower would be the Briggs and Stratton ETEK. This motor is light weight, outputs high power, and has a very good efficiency, even at high torques. Figure 5 shows efficiency vs. torque graph of the ETEK motor at 36 volts. The efficiency vs. torque line is represented by the solid black line. As can be seen, the efficiency of the motor remains very high, at about 85%, even as the torque approaches 200 lb-in. This high efficiency will allow the battery to run for a longer period of time on thick, wet grass.

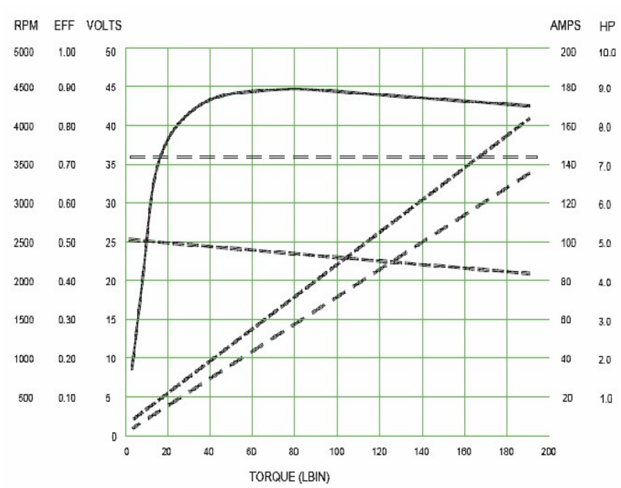

Figure 5[8]

MOTOR CONNECTION

One problem we encountered when we purchased the ETEK motor was that the output shaft was designed significantly differently than that of the stock motor we had. The stock motor output shaft was merely a cylinder that was threaded at the bottom. The ETEK output shaft was a hollow cylinder that was threaded on the inside and had a key on the outside. This forced us to consider new ways of attaching a blade to the motor. Work is still being done to create this connector. The model was have at this point can be seen in Figure 6. This piece consists of a sleeve that will fit to the outside of the output shaft. The sleeve will have a rectangular piece that will fit into the bottom, which will then hold the mower blade in place as it rotates. A bolt will be run through the whole apparatus to secure it all to the motor.

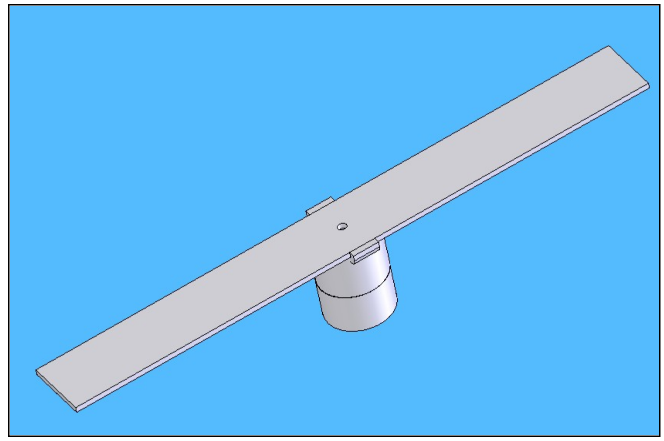

Figure 6

BLADE SELECTION

During the semester, we had an experienced design engineer overlook the project. He brought to out attention the fan effect of the blade. The fan created by the blade while cutting the grass leads to a loss in power. To measure this effect we ran a test of the motor without the blade attached, to determine the amount of power lost due to just the blade. From the previous power requirement test, we had that the initial spike was 100 amps and the running amperage was 10 amps. When the blade was removed, we measured the initial spike at 15 amps, while the running amperage was only 1.5 amps. This leads to the conclusion that the power lost to the fan effect of the blade was more than 200 watts. This seems like a huge loss of power simply to rotate the blade.

To try to lessen the amount of power lost to the fan effect of the blade, we have been looking into varying blade. We intend to purchase multiple blades for testing, to determine the best blade design that will reduce this loss in power.

FUTURE WORK

Over the course of the next semester we look to complete the following:

1. Complete the SolidWorks drawings of the lawn mower.
2. Purchase the batteries we will be using to run the lawn mower.
3. Purchase and test multiple blades and determine the best one for our final design.
4. Complete the fabrication of our lawn mower.
5. Test the new lawn mower and compare it the existing system.

This will all be completed and presented at an open house in May 2005.

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