COMPARATIVE ANALYSIS OF ELECTRIC MOWERS

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ABSTRACT

The comparative analysis of electric mowers was performed in this experiment to compare the efficiency of their power sources. In order to perform this analysis, troubleshooting was performed on the existing electric mower in the WVU Tech Engineering Lab building, which has not been operational in the past related projects. The criteria that determines the effectiveness of the mowers are the power outputs, the cost of use, and the emissions. It was found that six out of eight cells were not operational on the battery packs. The purchase of two new battery packs are needed in order to fully operate electric mower, and be able to perform field tests. Only numerical analysis was done to compare the power sources of the electric mower. It was found that electric mowers using lithium-ion batteries are the most cost effective ($0.134/use), and environmentally friendly ($CO_2 = 3$ lb/use) while the gas mowers have the highest power output ($\approx$2237 Watts).

INTRODUCTION

Landscaping services make any yard look impeccable but it comes with a price. The average American cannot be spending money on the luxuries of landscaping services but he/she can mow the lawn himself/herself. In order to mow the lawn a person would need a mower. The question is which one to buy, electric or gas? The purpose of our project is to compare the efficiency of an electric lawn mower and a gasoline mower. The following image shows the electric mower we analyzed.

Figure 1. Black & Decker Electric Mower [10]

The analysis was done by calculating the power output (cuts through tougher grass). The cost of use were determined by which mower cost is lower (retail value and operation cost). The emissions are considered in the analysis because not only do they harm the environment but also the owners health.

This project will be developed with a team consisting of two undergraduate students who have completed the Thermodynamics and Applied Thermodynamics. They will apply their course knowledge to the advancement of the project.

Purpose

Gasoline lawnmowers contribute heavily to air pollution [1]. They produce various emissions (CO, CO_2, CH_4, etc.) which in the long run affect the human health and the environment [2]. The primary objective of this project is to compare three power sources currently used on mowers (gas, lead acid battery, and lithium-ion) study of the electric mowers powered by lithium-ion batteries will add more value to the advancement of electric powered technology. The following image (Figure 2) shows a pie chart with the total U.S. greenhouse gas emissions by economic sector in 2012 with 32% share of electricity production and 29% share of transportation. Over 70% of the electricity production, and 90% of the transportation is from burning fossil fuels, and natural gas [3].
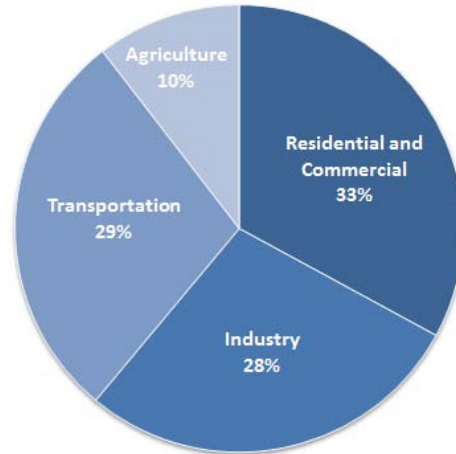
Figure 2. Total U.S. Greenhouse Gas Emissions by Economic Sector in 2012 [3]

Background

The lawnmower is a device that uses energy to rotate cutting blade(s) at high speeds to cut grass. The sources of energy can be: gasoline, electricity, or kinetic energy [4]. The lawnmower has been around since the 1800s, it was invented by English engineer Edwin Budding. The idea originally came from the scythe, used to cut grass to a more desirable height, and the lawnmower had proven to be more efficient device, in lawn cutting [5]. Over the years of technology advancements, the lawn mower has seen its share. In this paper, we will emphasize on the power source of the lawnmower.

Theory

In order to prove the feasibility of electric powered lawnmower, certain calculations will be used to compare efficiency and cost of use.

In order to obtain the efficiency, η_{th} (%), the following equations will be used [3],

1. For electric mower

$$P_{out} = Bat_V * Bat_i$$

$$n_{th} = \frac{P_{out}}{P_{in}}$$

2. For gasoline mower

$$W_{out} = \frac{T * RPM}{5252}$$

$$Q_{in} = n_{th} * W_{out}$$

$$n_{th} \approx 25 - 27\% \ [6]$$

where P_{in} is the input power of the mower, from lithium-ion battery, that will vary from a batteries capacity. P_{out} is the output power of the electric mower and will be a fixed value as stated in the manual. The efficiency will state how much of the power is being utilized. W_{out} is the output power generated by the gasoline mower. This varies from engine capacity. Q_{in} is the heat transformed into mechanical energy, and the η_{th} represents the efficiency. The following image shows the engine we analyzed in order to make comparison.

Figure 3. Briggs & Stratton 725ex Series Engine [10]

In order to obtain cost of use, we will need the cost of gasoline and the cost of electricity,

1. For electric mower

$$EM_{cost} = C_T * e_{cost}$$

2. For gasoline mower

$$GM_{cost} = g_{cost} * F_{ch}$$

Where C_T is the charge time, and e_{cost} is the price of electricity, we will be using the average cost in USA (Residential: 13.05¢/kWh) [7]. For the equation GM_{cost}, g_{cost} represents the average gas

price in USA (3.3 ±0.05 $/gal, depending on state) [8], and F_{ch} is the size of the fuel chamber. The cost for each mower will be calculated for every full refill when battery depleted/ fuel chamber is empty.

In order to obtain the charge time, C_T (hr), the following equation will be used [8],

$$C_T = \frac{Bat_{imax}}{C_{imax}}$$

Where Bat_{imax} is the max current the lithium ion battery can hold, and C_{imax} is the max current the charger can supply. The results of this equation can also be used to compare lithium-ion battery and lead/acid battery charge time.

Procedure

The procedure is relatively basic. The data for calculations are retrieved by testing the electric mower, from the battery specifications Bat_{imax} and Bat_v (24V, 40Ah), and from an equivalent gas mower's specifications (online information). For gasoline mower, we used a 190cc 7.25 series Briggs & Stratton engine, from the engine specifications Torque, and RPM were obtained. The efficiency (η_{th}) of the gas motor was obtained from online website that offered average gasoline engine efficiencies. The gasoline and electricity cost were obtained from online sources.

Due to an analysis of past projects relating to the electric mower, we were informed that the problem with the mower was in the power source. This meant a further investigation was needed. In order to troubleshoot the engine, we tested the condition of the charger by charging the battery for 24 hours. Furthermore, we measured the batteries voltage in series, between each cell, from the positive terminal to the negative terminal (V_{in}, V_{out}) using a multimeter. All the information gathered and calculated was inserted into an Excel spreadsheet to show organized tabulated results.

RESULTS

Observation

First, we tested the charger, and found that it was functioning sufficiently. The next step was to measure the voltage in the battery. This yielded a very low voltage reading when we measured

the battery. Upon further analysis of each individual cell, we found that six of the eight 3V cells, 4 cells per battery, were not functioning properly (had voltage lower than 2.8 V). We then investigated the best way to fix the battery. Due to the degree of the damage to the battery, we determined that the best solution was to completely replace the battery. However, due to insufficient funds, we were not able to purchase the replacement battery. At this point, we changed the focus of the report to examine the feasibility with numerical analysis only (no field tests).

Measurements

The following tables and figures were all done with data calculated from information gathered from resources.

The following table is an example representation of how the lithium-ion battery compares to a lead/acid battery. The first column represents the type of battery being studied. The following columns are all the parameters that are being compared.

Table 1: Comparisson of Batteries used in Lawn Mower			
Battery Type	Voltage (V)	Current (A)	Power (W)
*Lithium-Ion	25.6	40	1024
Lead Acid	24	17	408

*Tentative values of potential
 replacement batteries

Table 1: Comparisson of Batteries used in Lawn Mower			
Battery Type	Weight (lb)	Operation Time (hr)	Charge Time (hr)
*Lithium-Ion	29.2	2	2
Lead Acid	27.16	0.45	10

*Tentative values of potential
 replacement batteries

The following table is comparing the cost of use for every full refill after fuel has been depleted completely. The first column is the mower that is being studied. The second column represents the cost of the fuel (gas and electricity). The third column represents the consideration of a complete refill. The fourth column represents the total cost of use for every full refill after fuel being completely depleted.

Table 2: Cost of Use Comparison Table			
Mower	Fuel$_{cost}$	Full Capacity	Cost of use
Gas	3.3* ($/gal)	0.25 (gal)**	$ 0.825
Electric	13.05* (¢/kW)	1.024 (kW)	$ 0.261

*Price depends on the state
**Capacity depends on fuel tank

The following table is comparing the emission from the three mowers being studied. The amount of CO_2 being outputted by the mowers is in pound (lb) per max operation time. The values obtained of CO_2 emission were calculated with the Greenhouse Gas Equivalencies Calculator [11].

Table 3. Emission Comparison of Three Mowers Under Investigation			
Emission	Gas	Lead-Acid	Lithium-ion
CO_2	4.9 lb	0.684 lb	3 lb

CONCLUSION

The purpose of our project was to perform an in-depth comparison on the efficiency of electric mowers vs gasoline mowers. Initially, it was planned to repair the existing mower in the engineering lab to perform field tests, however due to insufficient funding, the project was reduced to a theoretical analysis of the mowers. Nevertheless, we were able to troubleshoot the mower enough to get the necessary information to perform a sufficient numerical examination of the electrical mower. Based on our results from the formulas listed earlier, it was confirmed that a lithium-ion powered electric mower is more cost efficient, and more environmentally safe than a conventional gasoline mower. It was also found that the use of an electric mower is not always the most practical. Charge time and lack of power are the two main issues with the electric

mower. A gasoline mower is considerably more expensive to operate, however it is more powerful, and more practical for use over a long period of time.

BIBLIOGRAPHY

[1]"Air Quality." EPA. Environmental Protection Agency, n.d. Web. 20 Sept.2014. <http://www.epa.gov/airquality/cleanair.html>

[2]Priest, M.w., D.j. Williams, and H.a. Bridgman. "Emissions from In-use Lawn-mowers in Australia." Atmospheric Environment: 657-64. Print.

[3] "Sources of Greenhouse Gas Emissions." Climate Change. Environmental Protection Agency, n.d. Web. 06 Dec. 2014. <http://www.epa.gov/climatechange/ghgemissions/sources.html>.

[4]Borja, Edson; Suarez, Juan; Cousin, Sebastian; Menello, Joe. "Report for Electric Mower Analysis."(2013). Print.

[5] Shukitis, Amber, and Erik Kortum. "The History of Lawn Mowers". Web. 11 Oct. 2014 <https: //honors.usf.edu/documents/Thesis/U03169766.pdf.>.

[6] "Power Systems & Efficiency". State Energy Conservation Office. Web. 13 Oct. 2014. <http://www.energyeducation.tx.gov/pdf/3100_lesson.pdf>.

[7] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Electricity Monthly Update. Web. 13 Oct. 2014. <http://www.eia.gov/electricity/monthly/update/end_use.cfm#tabs_prices-3>.

[8] "U.S. Energy Information Administration - EIA - Independent Statistics and Analysis." Gasoline and Diesel Fuel Update. Web. 12 Oct. 2014. <http://www.eia.gov/petroleum/gasdiesel/>.

[9] Fuller, Ken; Hildebrand, Matt; Mudie, Scott. "Optimization of an Electric-Powered Lawnmower."(2010).Print

[10] "725ex Series™." Push Mower Engine. Briggs and Stratton. Web. 13 Oct. 2014. <http://www.briggsandstratton.com/us/en/engines/push-mower-engines/725ex-series >

[11] "Greenhouse Gas Equivalencies Calculator." Clean Energy. Environmental Protection Agency, n.d. Web. 06 Dec. 2014. <http://www.epa.gov/cleanenergy/energy-resources/calculator.html>.