STEAM ENGINE LAWNMOWER: BOILER & HEATING SOURCE

A Baccalaureate thesis submitted to the Department of Mechanical and Materials Engineering
College of Engineering and Applied Science
University of Cincinnati

in partial fulfillment of the requirements for the degree of Bachelor of Science

in Mechanical Engineering Technology

by

Andrew Geiger

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Thesis Advisor: Professor Ahmed Elgafy, Ph.D.
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- Professor Ronald Singleton
- Brian Petty, Electrical Engineer
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ABSTRACT

When thinking about today’s engineering, more and more companies are trying to convert their technologies to a green approach. Many people are trying to stray away from relying on gasoline engines and are incorporating different common everyday energies as a power source. So when deciding a senior design, my partner O.P. and I decided we wanted to incorporate a green energy into something, and settled with the idea of changing over a lawn mower to go green. The project entailed us to convert a carbureted lawn mower engine into a steam induced engine. A normal lawn mower runs off a gas combustion system in which fuel combust and causes the piston to move, powering the system. In our application, we would induce steam into the engine via a modified steam boiler. The steam would induce into our engine and power the piston, based off a few engine modification we must do to camshaft of the lawn mower engine. The camshaft modification was the most important part of our lawn mower engine, because it is what drives the intake and exhaust valves, which in turn will let in the applied pressure into our engine.

In this report, I will explain what must be done to the internal working of our lawn mower engine, and how we were able to accomplish that. I will show what calculations were used and what was needed in order for us to assure that our system was safe and reliable. Testing the engine will also be covered, and the steps that were needed to be taken to adjust and modify once the system was already tested. As far as the modification of the heating element and boiler, my partner’s report will be in depth about those matters.
INTRODUCTION

PROBLEM STATEMENT
Steam is a cheap and fairly easy energy to attain that can be used for several different applications. Steam was widely used in the 20’s and 30’s in car engines, originating from locomotives, but didn’t pan out as well in cars because they could not accelerate very quickly and couldn’t maintain high speeds for long periods of time. With those drawbacks, a steam engine would be perfect for a lawn mower application. When cutting grass, you don’t have to accelerate fast and it wouldn’t be traveling at high speeds what so ever. In today’s modern world, engineers are constantly looking to introduce new greener energies in order to reduce the pollutants that are given off in every day applications.

Converting a carbureted lawn mower engine into a steam based, harmful emissions would be greatly reduced and lawns could be cut by simply boiling a specific amount of water. Andrew Geiger will be handling the internal components of the lawnmower engine for modifications to steam. Op. Fapohunda will be dealing with the fabrication of the boiler and the heating source needed to boil the water.

INTERVIEWS
Prof. Amir Salehpour likes the concept of the steam based lawn mower. He believes it should be done on a smaller scale, such as a push-mower instead of a riding-mower. He wanted us to be sure to focus on the amount of energy loss at different stages of the steam engine. (1)

Harvey Thompson has schema in the steam engine field, and believes with this design it would give off next to no harmful toxins. He wanted to emphasize the importance of getting our burn ratio to the utmost correctness with minimal error, therefore we have minimal energy loss. (2)

John Southwood wanted to do a deep-dive into different energy methods that could be used to power the steam engine and heat the water. We concluded that an electric battery would be most feasible for our application, but other design ideas were touched on such as solar panels, nitrogen energy, etc. (3)

See appendix A for complete research on interviews.
EXISTING PRODUCTS

STEAM INDUCED LAWN MOWER ENGINE

There are three examples of steam engine applications listed in this report. They are Steam Induced Lawn Mower Engine, Self-Propelled Electric Gas Mower and Industrial Steaming Equipment Used for Cooking.

In this particular steam induced lawn mower engine, the camshaft must be removed (Figure 1) from the engine and modified so that it can run solely off compressed error.

![Figure 1 - Camshaft removed from Engine](image1)

The timing is then modified so that it only has a power and exhaust stroke. Therefore you must weld on an extra lobe to the opposite side (as shown in Figure 2), then grind at the weld until it is smooth and looks like the original side.

![Figure 2 - Add on extra Lobe through Welding](image2)
The Lobe should look uniform and smooth on the edges as it does in Figure 3. (4)

Figure 3 - Camshaft with additional lobe, weld spatter grinded down
SELF-PROPELLED ELECTRIC GAS MOWER

The second application is a regular push lawn mower used in everyday households. This specific example is a standard Honda Push Lawn Mower. It can be self-propelled by pulling in the clutch, power will be applied to the back to wheels and the lawn mower will push itself. This lawn mower is driven by a 190cc engine that can reach up to 4.0mph, that is also belt driven. (5) It is an air-cooled 4-stroke OHC engine, so it uses a carburetor that runs off gasoline and oil. Figure 4 shows how the engine sits centered and on top of the lawn mower frame and propeller. It cuts the grass and is forced into the grass catcher attached to the mower.

Figure 4 - Honda 21”
GCV190 Self-Propelled
Lawn Mower
INDUSTRIAL STEAMING EQUIPMENT FOR COOKING

The third and final application where a steam engine is used is in the food industry. Shown below is the system of an Industrial steaming Equipment used for cooking. (Figure 5) These act as pressure cookers, but can cope with much higher pressure than pressure cookers. These boilers are welded from steel plates that are up to 35 millimeters thick, which can reach up to 435 psi. This system is a digital pad in which parameters can be set or modified, allowing complete user control and observation. (For the full research on these applications, see Appendix A)

Figure 5 - Steaming Equipment for Cooking

None of the existing products and methods considered comes fairly close to our steam engine lawn-mower application. This is because our design is relatively new and hasn’t really been implemented much in the United States. In proving that a lawnmower can successfully run off steam, other possibilities in different applications are endless. Before we moved forward, we had to consider the needs of the customer as it pertains to this application.
SURVEY ANALYSIS

The eight features that were found to be most favored from the research were put into a survey. The purpose of the survey was to determine the importance of the eight customer features that would be designed for in the creation of a steam-engine operated lawn mower. The ratings were listed from 1-5 with 5 being the most important. It also asked how much they would be willing to pay for such a system by choosing a dollar amount range. The survey was handed out to peers on the university campus, in which there were fifteen responses. Table 1 shows that after analyzing the results, the importance of each customer feature was no more two percent different from the next. Environmental friendliness was the most important feature at seventeen percent, while price and safety were deemed as the least important at ten and eight percent respectively. The cost of how much the respondents were willing to pay (retail) for the fully designed steam engine lawn mower came out to be about $800. (For the complete survey results see Appendix B)

<table>
<thead>
<tr>
<th>Customer Features</th>
<th>Customer Importance</th>
<th>Relative Weight</th>
<th>Relative Weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Environmental Friendliness</td>
<td>3.3</td>
<td>0.17</td>
<td>17%</td>
</tr>
<tr>
<td>Efficiency</td>
<td>4.4</td>
<td>0.15</td>
<td>15%</td>
</tr>
<tr>
<td>Quiet Operation</td>
<td>3.3</td>
<td>0.14</td>
<td>14%</td>
</tr>
<tr>
<td>Ease of Use</td>
<td>4.7</td>
<td>0.12</td>
<td>12%</td>
</tr>
<tr>
<td>Reliability</td>
<td>4.8</td>
<td>0.12</td>
<td>12%</td>
</tr>
<tr>
<td>Ease of Maintenance</td>
<td>4.3</td>
<td>0.11</td>
<td>11%</td>
</tr>
<tr>
<td>Price</td>
<td>4.3</td>
<td>0.10</td>
<td>10%</td>
</tr>
<tr>
<td>Safety</td>
<td>3.9</td>
<td>0.08</td>
<td>8%</td>
</tr>
</tbody>
</table>

With the customer features defined, Product Objectives were developed as a way to obtain measurable results.
PRODUCT FEATURES AND OBJECTIVES

The Product Features are the same as the customer features on the survey. They are listed in order of most important in accordance with the survey. This importance level was determined from our survey results, by multiplying the customer importance and the design multiplier. Under each feature are Product Objectives. Product Objectives are goals in which to meet the customer features. The customer features obtained were translated into measurable variables to determine if the Product Objectives were met.

1. Environmental Friendliness (17%)
   a. No gas pollutants involved
   b. Steam exhaust gives minimal/no pollutant waste

2. Efficiency (15%)
   a. Burn ratio calculation will result in minimal water usage

3. Quiet Operation (14%)
   a. Engine noise output is very little
   b. Steam exhaust is relatively quiet

4. Ease of Use (12%)
   a. Engine utilizes water, no fuel
   b. Handle bars

5. Reliability (12%)
   a. Fabricated parts made out of coated steel
   b. Energy readily available with rechargeable battery

6. Ease of maintenance (11%)
   a. Use of rust resistant/durable materials
   b. Built using standard parts

7. Price (10%)
   a. Be less than or equal to a $1000 retail price
   b. Built using standard parts

8. Safety (8%)
   a. Guards for moving parts
   b. Guards for heating/cooling elements
   c. Nozzle to divert steam pressure
   d. No exposed wiring

After coming up with the Product Objectives, the next step for us to accomplish was to analyze and determine the importance of each.
ENGINEERING CHARACTERISTICS

The Product Objectives were then put into a Quality Function Deployment labeled as Engineering Characteristics and were cross referenced with all the Product Features and is weighted to see the importance of each to the design. The designer multiplier was justified based off certain customer features that we viewed as most important from an engineering standpoint. (For complete Quality Function Deployment, see Appendix C)

Table 2 – Engineering Characteristics

<table>
<thead>
<tr>
<th>Engineering Characteristics</th>
<th>Relative Importance</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Exhaust</td>
<td>24%</td>
</tr>
<tr>
<td>Engine Operation</td>
<td>18%</td>
</tr>
<tr>
<td>Standard Components</td>
<td>12%</td>
</tr>
<tr>
<td>Material</td>
<td>10%</td>
</tr>
<tr>
<td>Rechargeable Battery</td>
<td>10%</td>
</tr>
<tr>
<td>Burn Ratio</td>
<td>9%</td>
</tr>
<tr>
<td>Handle Bar</td>
<td>6%</td>
</tr>
<tr>
<td>Guards</td>
<td>6%</td>
</tr>
<tr>
<td>No Exposed Wiring</td>
<td>4%</td>
</tr>
</tbody>
</table>

After the importance of the Product Objectives and Engineering Characteristics were realized, a Schedule and Budget could be developed. (For a detailed view on the Product Objectives, see Appendix D)
CALCULATIONS

Designing the steam engine lawnmower, there were a lot of calculations that needed to be accounted for.

Our regulator would induce the steam into the engine ranging from 15-30 psi, so we had to be sure that the internal working of the lawn mower engine could handle the applied pressure. This entailed us being sure that the modified lobes on the camshaft could handle the pressure, since that was the modifications we made with JB Weld. I did this by verifying a few values on their website:

JB Weld can withstand constant pressure (up to 3900 psi) at 500 °F (jbweld.com/faqs).

This entailed us to believe JB Weld would be the most suitable substance to from the lobes out of, being that we would not be operating anywhere close to the tensile strength of JB Weld nor would we be applying 500 °F, so we were safe to use that material for our camshaft lobes. With knowing this information, I just had to calculate for the mass flow rate, to be sure we were in those parameters, which we were as you can see with the calculations below.

This was the only calculation I had to worry about, because research shows that the JB weld could withstand our pressure at a constant rate, so the time that we were applying steam to our engine is obsolete (for internal pressure purposes).

**DESIGN CALCULATIONS: MASS FLOW RATE**

\[ W = \dot{m} \cdot LHV \rightarrow \text{Latent Heat of vaporization for water} \]

\[ 20\% \text{ added to Power as safety factor} = 1.68 \text{ KW} \]

\[ 1.68 \text{ KW} = \dot{m} \cdot 2260 \frac{KJ}{kg} \]

\[ \frac{1.68}{2260} = \dot{m} \]

\[ \dot{m} = 7.4 \times 10^{-4} \frac{kg}{s} \rightarrow \text{Mass flow rate} \]

\[ \dot{m} = 7.4 \times 10^{-4} \frac{kg}{s} \rightarrow 16.3 \frac{lbm}{s} \]

This calculation shows our mass flow rate that is being induced into the engine is only 16.3 lbm/s. This is by far acceptable for the engine and the modified camshaft with the JB Weld.
My partner and I had three different parts to fabricate. We had to fabricate the boiler from a simple air tank, a heating source from a hot water heating element, and the engine to allow it to run off compressed air/steam. The heating element and boiler were handled by my partner, while I worked mechanically on the engine internally, fabricating the camshaft.

**CAMSHAFT**

Our original Camshaft (Fig. 6) shows how it looked originally, there were only two timing lobes, angled a certain way for timing issues. Figure 7 shows the modified timing lobes that were created out of JB Weld and a small lobe template. We cut a piece of steel that had the exact arc radius of the camshaft and was an exact replica size wise of the original lobes. This was done so when we made our new lobes from the JB Weld, we could file the weld down to the appropriate size and shape as the pre-existing lobe. This assured us both the created lobes would be precisely the same profile. The modified lobes were created by creating a support fixture for us to put the JB Weld in, once the fixture was made we put the mixed JB Weld into the cardboard fixture, and let it set over night. It took roughly 14-16 hours for the Weld to be completely firm and full strength. Once this was done, we removed what we could of the cardboard holding fixture and then used a file and grind wheel to file down the block of JB Weld down to the appropriate lobe side, in accordance to our template we made.

The purpose of the extra timing lobes on the camshaft was because it would allow the engine to have a 2-1 intake ratio from the original camshaft design. This means the engine would intake twice as much steam as it would have before, allowing more power to induce and the piston to cycle back and forth. This would work by the timing lobes striking the lifters, which are shown in Figure 8. They are what will open the intake/exhaust valves, allowing steam into either valve. The placement of the camshaft is shown in Figure 9. The camshaft spins based off the teeth of the crankshaft, so it was important that we aligned the camshaft correctly with the crankshaft or there would be a timing issue.
The Lifters shown in Figure 8 are actuated by the timing lobes that are on the camshaft. Figure 9 shows the proper placement of the camshaft, as mentioned before, it was very important that the keyed groove on the crankshaft matched up with the keyed groove teeth of the camshaft in order to assure the timing was correct and the engine wouldn’t stall.
TESTING

There were a few different tests we had to do on our whole lawn mower system, but I just cover the internal engine testing in my report. My partner covers the testing and pressurizing of the boiler, my report simply focuses on the internal engine testing of the lawn mower.

Once the lobes were created and modified down to the desired profile using the template, the camshaft was placed back in the engine, being sure the timing key slots were matched up between the crankshaft and camshaft. Once this was done we did a hand test of the crankshaft to make sure our lobes were holding up and working as they should. This was done by simply turning the crankshaft by hand, which in turn rotated the camshaft, applying the timing lobes to the lifters and causing the intake/exhaust valves to open and close. By doing this, we could see if there would be stalling in the engine by simply watching the intake and exhaust valves to see if they were open at the same time at any point. This was the case, when the intake valves was closing back up, the exhaust valve would open slightly early, causing both valves to be open at the same time. This would cause a stalling issue, and was due to slight inaccuracies with the modified timing lobes, one was slightly larger than the other, causing the intake to be open longer then the dwell time of the exhaust valve. With seeing that, I removed the camshaft and filed away more of the intake lobe, shortening its time it was open. This in turn caused the intake valve to close quicker, before the exhaust valve opened, eliminating the timing issue.

Once the timing issue was solved and we verified that neither the valves were open at the same time, we could test our engine with compressed air. We used the shop hose at half strength, 45 psi, through the air intake part of the engine. We found that we were having trouble finding TDC, top dead center, for the flywheel. We kept moving it around until finally the air caught the piston in the correct position and the flywheel spun on its own when applying the air. The most important thing was to mark the location the flywheel needed to be in so we could apply the air and it would spin the flywheel on its own.
CONCLUSION

Overall this project turned out very well. We hit a few rough spots in the research, as well as the fabrication process. There was a time when we had serious doubt in being able to pull off this project, but with much research and help from resources such as our professors, the internet, and some steam enthusiast, we were able to think through the problems and come up with solutions on our own. We were able to prove the theory that a lawn mower off compressed air and steam by showing the engine running off of our shop air house and as well as our boiler applying steam into the engine. We were able to achieve 30 psi easily inducing into the engine, and that is what all of the users online were operating at when they were using their steam lawn mowers to actually cut grass.

Figure 10 - Steam Engine Lawn Mower

Above shows our finished product, the Steam Engine Lawn Mower. Further applications could be applied to this project such as incorporating a condenser in order to re use some of the exhaust steam. Other ideas could be applied to our external energy source to make our lawn mower even more efficient. Overall, I am extremely happy with the success we were able to achieve with creating a Steam Engine Lawn Mower!
STEAM ENGINE LAWNMOWER:
Internal Engine Modifications
Andrew Geiger

SCHEDULE AND BUDGET

SCHEDULE
The schedule measures 28 weeks long. It starts with the Proof of Design phase on October 16th and ends with the Final Project Report on April 7th. Between these dates Table 3 shows the scheduling of designing, modeling, ordering, assembly and testing with a break in the middle. (For the complete Schedule, see Appendix E)

Table 3 - Schedule

<table>
<thead>
<tr>
<th>Tasks</th>
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<th>Dec</th>
<th>Jan</th>
<th>Feb</th>
<th>March</th>
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<tr>
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<td>14</td>
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<tr>
<td>Model Lawnmower</td>
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<td></td>
<td></td>
</tr>
<tr>
<td>Analysis &amp; Design of Battery</td>
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<tr>
<td>Model Battery</td>
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<td>Analysis of steam engine</td>
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<td>Design Calculations</td>
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<td>Design Freeze</td>
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<td>Bill of materials</td>
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<tr>
<td>Order parts</td>
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<td>16</td>
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<td>Assembly and Testing</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>24</td>
</tr>
</tbody>
</table>

BUDGET
The budget is a list of every expense that is involved with the project. The proposed cost to design and build the steam engine lawn-mower is estimated to be about $600. The actual cost came out to $165, almost 6 times less than forecasted. (For the detailed budget, see Appendix F)

Table 4 - Budget

<table>
<thead>
<tr>
<th>Components</th>
<th>Forecasted Cost</th>
<th>Actual Cost</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Engine</td>
<td>$300</td>
<td>$35</td>
</tr>
<tr>
<td>Engine Components</td>
<td>$75</td>
<td>$30</td>
</tr>
<tr>
<td>Heating element/Energy source</td>
<td>$75</td>
<td>$20</td>
</tr>
<tr>
<td>Electrical Components</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>Miscellaneous Parts/Services</td>
<td>$100</td>
<td>$30</td>
</tr>
<tr>
<td>Lawnmower</td>
<td>$600</td>
<td>Donated</td>
</tr>
<tr>
<td>Total</td>
<td>$600</td>
<td>$165</td>
</tr>
</tbody>
</table>
WORKS CITED

APPENDIX A- RESEARCH

Interview with University of Cincinnati Professor: Amir Salehpour of College of Engineering & Applied Science 2600 Clifton Ave., Cincinnati OH 45221 08/30/13

Associate professor in the department of mechanical and materials engineering. Familiar with steam engine designs
Possible ideas for energy source: Coal, Electric motor, Hydrogen battery
Asked him about the possibility of using solar panels as an external energy source, he felt they would be too expensive and time consuming.
He mentioned that we should limit our project to a smaller scale. So using a push lawnmower would make a lot more sense than a riding one.
Felt that our project was feasible but was worried about energy loss between stages of energy conversion.
Was not aware of a current design/product out there that meets our design specifications.

Overall, he likes the theory concept of energy conversion and the use of a steam powered engine.

Interview with potential non-engineering customer: Harvey Thompson 498 Lamesa Drive Columbus, OH 43004 09/25/11

We wanted to get the perspective of a consumer, a potential buyer with little-to-no engineering experience.
The first question he asked was how this would be more beneficial than using a gas-powered lawnmower engine.
With some customer features already written up, we were able to explain to him, in layman terms, how this concept could prove to be better than a regular lawnmower.
How much water would be needed for a typical mow? We would have to figure out the burn ratio from water to steam.
Cleaner engine, less build-up = better maintenance.
Learning curve required? How long would it take the average person?
Eco-friendly?

Important features to consider: easy to maintain, easy to use, cleaner engine and less build-up, environmentally friendly, overall cost.
Interview with Personal Consultant, John Southwood: 205 Lyon St. Cincinnati, OH 45219 08/26/13
Engineer Graduate that has multiple inventions he has made on his own.

A push mower was found to be most feasible over a riding lawn mower. Brainstormed on ideas of what to change the energy to, and decided a steam based engine has a high engine efficiency and a positive environmental effect. Collaborated on different ideas on methods of getting the water boiling to induce into the engine. Solar panels would be most efficient as an external energy source because solar energy would have a minimal energy loss when converting to heat. Discussed the design of the solar panels and placement so that we could achieve maximum solar energy.

John believes this is something that can be done, and looks forward to providing insight in the future.
Steam-induced ready lawn mower engine

Remove the camshaft from the engine and modify it so that it will run on compressed air or steam. To do this you must modify the timing lobes. The lobes on the gas engine allow the engine to perform the intake and exhaust cycle. Modify the timing so that it only has a power and exhaust stroke. Therefore you must weld on an extra lobe to the opposite side, then grind at the weld until it is smooth and looks like the original side. Apply the modified camshaft into the crankcase, turn the engine while looking at the valves. Be sure that one valve should open as the piston goes down and the other should open right as the piston goes up. If both valves are open at the same the engine will stall.

Spatter from the weld could get on other engine components, so improved measures should be taken when welding. Such as covering up any components that could be effected by spatter. Appropriate spacing should be used between lobes to optimize engine efficiency.

$200 USD


08/28/13
Honda 21'' Variable Speed Self-Propelled Electric Start Gas Mower

<table>
<thead>
<tr>
<th>Engine</th>
<th>GCV190</th>
</tr>
</thead>
<tbody>
<tr>
<td>Deck Material</td>
<td>NeXite®</td>
</tr>
<tr>
<td>Cutting Width</td>
<td>21''</td>
</tr>
<tr>
<td>Mowing Height Range</td>
<td>3/4'' - 4''</td>
</tr>
<tr>
<td>Mowing Height Adjustments</td>
<td>7</td>
</tr>
<tr>
<td>Drive Control</td>
<td>Cruise Control</td>
</tr>
<tr>
<td>Transmission</td>
<td>Hydrostatic Variable Speed</td>
</tr>
<tr>
<td>Ground Speed</td>
<td>0 To 4.0 Mph</td>
</tr>
<tr>
<td>Starter</td>
<td>Electric/Recoil</td>
</tr>
<tr>
<td>Choke System</td>
<td>Automatic</td>
</tr>
<tr>
<td>Drive</td>
<td>Belt</td>
</tr>
<tr>
<td>Dry Weight</td>
<td>102 Lbs.</td>
</tr>
<tr>
<td>Operating Weight</td>
<td>104 Lbs.</td>
</tr>
</tbody>
</table>

There should be a speed adjustment on it, or different automated levels. For instance give it three propelled speeds: Slow, Medium, and Fast. This way it gives the customer more features suitable for themselves. $900 USD

08/28/13
**Industrial Steaming Equipment for Cooking**

As this is not a steam engine for a lawnmower, but cooking instead. The internal components do work very similarly, with a boiler, feed water heater, and the appropriate nozzle placement, and also a digital reading and level variation option. This kind a system would be a good system to model our engine off of because of the precision and adequate materials they use within. If we were able to configure an electrical monitoring pad like they have, it would help us greatly for monitoring purposes.

With the pad being electrical, it could short wire or electrical components could go wrong, completely making the monitoring or configuring useless. With this being capable of holding 600L it maybe a little too much or take too much pressure when trying to get the desired steam level. $2500 USD

**Technical parameters**

<table>
<thead>
<tr>
<th>Model</th>
<th>JL-XKLG-Q</th>
</tr>
</thead>
<tbody>
<tr>
<td>Power</td>
<td>4+0.75 kw/380v</td>
</tr>
<tr>
<td>Capacity</td>
<td>60L</td>
</tr>
<tr>
<td>Dimension</td>
<td>2210x2400x1540mm</td>
</tr>
<tr>
<td>Mixer rotate speed</td>
<td>23r/min</td>
</tr>
<tr>
<td>water pressure</td>
<td>0.1-0.05mpa</td>
</tr>
<tr>
<td>Designed temperature</td>
<td>260 Celsius degree</td>
</tr>
</tbody>
</table>

APPENDIX B – SURVEY WITH RESULTS

STEAM ENGINE LAWN MOWER
CUSTOMER SURVEY with Results

This project will consist of building a steam engine based lawn mower capable of performing the same tasks that a regular lawn mower would perform, but with increased benefits to aid in the user’s everyday chore life. This survey will be used to weigh specific lawn mower operations and features.

How important is each feature to you for the design of a steam engine based lawn mower?
Please circle the appropriate answer.  

<table>
<thead>
<tr>
<th>Feature</th>
<th>1 = low importance</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 = high importance</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(5)</td>
<td>5(10)</td>
<td>N/A</td>
</tr>
<tr>
<td>Environmental Friendliness</td>
<td>1</td>
<td>2(3)</td>
<td>3(7)</td>
<td>4(2)</td>
<td>5(3)</td>
<td>N/A</td>
</tr>
<tr>
<td>Reliability</td>
<td>1</td>
<td>2</td>
<td>3</td>
<td>4(3)</td>
<td>5(12)</td>
<td>N/A</td>
</tr>
<tr>
<td>Safety</td>
<td>1</td>
<td>2</td>
<td>3(6)</td>
<td>4(5)</td>
<td>5(4)</td>
<td>N/A</td>
</tr>
<tr>
<td>Price</td>
<td>1</td>
<td>2</td>
<td>3(3)</td>
<td>4(5)</td>
<td>5(7)</td>
<td>N/A</td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>1</td>
<td>2</td>
<td>3(2)</td>
<td>4(6)</td>
<td>5(7)</td>
<td>N/A</td>
</tr>
<tr>
<td>Quiet Operation</td>
<td>1(1)</td>
<td>2(3)</td>
<td>3(6)</td>
<td>4</td>
<td>5(5)</td>
<td>N/A</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>2(2)</td>
<td>3</td>
<td>4(3)</td>
<td>5(10)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

How satisfied are you with your current lawnmower and its engine?
Please circle the appropriate answer.  

<table>
<thead>
<tr>
<th>Feature</th>
<th>1 = very UNsatisfied</th>
<th>2</th>
<th>3</th>
<th>4</th>
<th>5 = very satisfied</th>
<th>Avg</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td>1</td>
<td>2(1)</td>
<td>3(4)</td>
<td>4(5)</td>
<td>5(5)</td>
<td>N/A</td>
</tr>
<tr>
<td>Environmental Friendliness</td>
<td>1(1)</td>
<td>2(6)</td>
<td>3(6)</td>
<td>4</td>
<td>5(2)</td>
<td>N/A</td>
</tr>
<tr>
<td>Reliability</td>
<td>1(1)</td>
<td>2(1)</td>
<td>3(4)</td>
<td>4(7)</td>
<td>5(2)</td>
<td>N/A</td>
</tr>
<tr>
<td>Safety</td>
<td>1</td>
<td>2(2)</td>
<td>3(3)</td>
<td>4(7)</td>
<td>5(3)</td>
<td>N/A</td>
</tr>
<tr>
<td>Price</td>
<td>1</td>
<td>2(1)</td>
<td>3(9)</td>
<td>4(4)</td>
<td>5(1)</td>
<td>N/A</td>
</tr>
<tr>
<td>Ease of maintenance</td>
<td>1</td>
<td>2(2)</td>
<td>3(7)</td>
<td>4(4)</td>
<td>5(2)</td>
<td>N/A</td>
</tr>
<tr>
<td>Quiet Operation</td>
<td>1(1)</td>
<td>2(6)</td>
<td>3(8)</td>
<td>4</td>
<td>5</td>
<td>N/A</td>
</tr>
<tr>
<td>Efficiency</td>
<td>1</td>
<td>2(4)</td>
<td>3(4)</td>
<td>4(6)</td>
<td>5(1)</td>
<td>N/A</td>
</tr>
</tbody>
</table>

How much would you be willing to spend (retail) for this project?
$50 -$100,  $100-$200,  $200-$500,  $500-$1000,  $1000-$2000+

Thank you for your time.
# APPENDIX C – QUALITY FUNCTION DEPLOYMENT (QFD)

<table>
<thead>
<tr>
<th>Steam Engine Lawn-mower</th>
<th>Handle Bar</th>
<th>Steam Exhaust</th>
<th>Standard Components</th>
<th>Material</th>
<th>Rechargeable Battery</th>
<th>Guards</th>
<th>No Exposed Wiring</th>
<th>Burn Ratio</th>
<th>Engine Operation</th>
<th>Customer Importance</th>
<th>Designer’s Multiplier</th>
<th>Current Satisfaction</th>
<th>Planned Satisfaction</th>
<th>Improvement ratio</th>
<th>Modified Importance</th>
<th>Relative weight</th>
<th>Relative weight %</th>
</tr>
</thead>
<tbody>
<tr>
<td>Ease of Use</td>
<td>9</td>
<td>3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.7</td>
<td>1</td>
<td>3.93</td>
<td>4</td>
<td>1.0</td>
<td>4.8</td>
<td>0.12</td>
<td>12%</td>
</tr>
<tr>
<td>Environmental Friendlines</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>1.1</td>
<td>2.73</td>
<td>5</td>
<td>1.8</td>
<td>6.7</td>
<td>0.17</td>
<td>17%</td>
</tr>
<tr>
<td>Reliability</td>
<td>3 9 9 9 1 1 1 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.8</td>
<td>1.1</td>
<td>3.53</td>
<td>3</td>
<td>0.8</td>
<td>4.5</td>
<td>0.12</td>
<td>12%</td>
</tr>
<tr>
<td>Safety</td>
<td>3 9</td>
<td>9 9 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.9</td>
<td>1</td>
<td>3.6</td>
<td>3</td>
<td>0.8</td>
<td>3.2</td>
<td>0.08</td>
<td>8%</td>
</tr>
<tr>
<td>Price</td>
<td>9 9 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.3</td>
<td>1</td>
<td>3.33</td>
<td>3</td>
<td>0.9</td>
<td>3.8</td>
<td>0.10</td>
<td>10%</td>
</tr>
<tr>
<td>Ease of Maintenance</td>
<td>3 3</td>
<td>3 1 3</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.3</td>
<td>1.1</td>
<td>3.4</td>
<td>3</td>
<td>0.9</td>
<td>4.2</td>
<td>0.11</td>
<td>11%</td>
</tr>
<tr>
<td>Quiet Operation</td>
<td>9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>3.3</td>
<td>1</td>
<td>2.46</td>
<td>4</td>
<td>1.6</td>
<td>5.4</td>
<td>0.14</td>
<td>14%</td>
</tr>
<tr>
<td>Efficiency</td>
<td>9 3 3 3 1 9 9</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>4.4</td>
<td>1.1</td>
<td>3.26</td>
<td>4</td>
<td>1.2</td>
<td>5.9</td>
<td>0.15</td>
<td>15%</td>
</tr>
<tr>
<td>Abs. importance</td>
<td>1.36</td>
<td>5.32</td>
<td>2.73</td>
<td>2.27</td>
<td>2.18</td>
<td>1.35</td>
<td>0.98</td>
<td>2.03</td>
<td>4.10</td>
<td>22.3</td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
<td>38.5</td>
</tr>
<tr>
<td>Rel. importance</td>
<td>0.06</td>
<td>0.24</td>
<td>0.12</td>
<td>0.10</td>
<td>0.10</td>
<td>0.06</td>
<td>0.04</td>
<td>0.09</td>
<td>0.18</td>
<td>1.0</td>
<td></td>
<td></td>
<td></td>
<td></td>
<td>1.0</td>
<td></td>
<td></td>
</tr>
</tbody>
</table>
APPENDIX D – PRODUCT OBJECTIVES

OBJECTIVES
Based on the steam engine lawn-mower customer survey, the product objectives are the list of features that have been taken into consideration. The following is a list of product objectives and how they will be obtained or measured to ensure that the goal of the project is met.

1. Environmental Friendliness (17%)
   a. No gas pollutants involved
   b. Steam exhaust gives minimal/no pollutant waste

2. Efficiency (15%)
   a. Burn ratio calculation will result in minimal water usage

3. Quiet Operation (14%)
   a. Engine noise output is very little
   b. Steam exhaust is relatively quiet

4. Ease of Use (12%)
   a. Engine utilizes water, no fuel
   b. Handle bars

5. Reliability (12%)
   a. Fabricated parts made out of coated steel
   b. Energy readily available with rechargeable battery

6. Ease of maintenance (11%)
   a. Use of rust resistant/durable materials
   b. Built using standard parts

7. Price (10%)
   a. Be less than or equal to a $1000 retail price
   b. Built using standard parts

8. Safety (8%)
   a. Guards for moving parts
   b. Guards for heating/cooling elements
   c. Nozzle to divert steam pressure
   d. No exposed wiring
APPENDIX E – SCHEDULE

Andrew Geiger (Green)
O.P. Fapohunda (Red)
Both (Yellow)

TASKS

Content review (advisor) 9

Proof of Design Agree (advisor) 16

Concepts/Selection (advisor) 16

Report Due 16

3D Model - (Lawn mower system) 7

3D Model - (Battery) 7

3D Model - (Steam-engine system) 14

Design Calculations 5

Design Freeze 15

Bill of Materials 9

Shop Drawing 9

Order Parts 16

Fabrication 23

Design Pres. To Faculty 27

Report Due to Advisor 3

Assembly 20

Testing 27

Modification 6

Final Testing 13

Advisor Demonstration 24

Tech Expo 3

Proj. Presentation to Faculty 7

Project Report Advisor Review 14

Library PDF File in BB 23
## APPENDIX F – BUDGET

<table>
<thead>
<tr>
<th>Materials, Components, Labor</th>
<th>Forecasted Amount</th>
<th>Actual</th>
</tr>
</thead>
<tbody>
<tr>
<td>Steam Engine</td>
<td>$300</td>
<td>$35</td>
</tr>
<tr>
<td>Lawnmower</td>
<td>$0 (Donated)</td>
<td></td>
</tr>
<tr>
<td>Engine Components (Nozzles, Tubing, O-rings, Rods)</td>
<td>$75</td>
<td>$30</td>
</tr>
<tr>
<td>Battery</td>
<td>$75</td>
<td>$20</td>
</tr>
<tr>
<td>Electrical Components (Wiring, Harness, Charging Device)</td>
<td>$50</td>
<td>$50</td>
</tr>
<tr>
<td>Miscellaneous Parts/Services</td>
<td>$100</td>
<td>$30</td>
</tr>
<tr>
<td><strong>Total:</strong></td>
<td><strong>$600</strong></td>
<td><strong>$165</strong></td>
</tr>
</tbody>
</table>
## APPENDIX G – BILL OF MATERIALS

<table>
<thead>
<tr>
<th>Item #</th>
<th>Part Number</th>
<th>Description</th>
<th>Qty</th>
<th>Materials</th>
</tr>
</thead>
<tbody>
<tr>
<td>1</td>
<td>TB426</td>
<td>Push Lawn Mower</td>
<td>1</td>
<td>Steel Frame, Plastic Wheels</td>
</tr>
<tr>
<td>2</td>
<td>69269</td>
<td>5 Gal. Air Compressor Tank</td>
<td>1</td>
<td>Mild Steel</td>
</tr>
<tr>
<td>3</td>
<td>-</td>
<td>Safety Gauges</td>
<td>2</td>
<td>-</td>
</tr>
<tr>
<td>4</td>
<td>84931377</td>
<td>Quick Connect Fittings</td>
<td>3</td>
<td>3/8 Thread, Brass</td>
</tr>
<tr>
<td>5</td>
<td>-</td>
<td>Heating Element</td>
<td>1</td>
<td>Nichrome</td>
</tr>
<tr>
<td>6</td>
<td>-</td>
<td>Safety Valve</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>7</td>
<td>-</td>
<td>Ext. Energy (Battery/Outlet)</td>
<td>1</td>
<td>-</td>
</tr>
<tr>
<td>8</td>
<td>NT459302</td>
<td>Hose with Fittings</td>
<td>1</td>
<td>Rubber lining and Nylon</td>
</tr>
<tr>
<td>9</td>
<td>-</td>
<td>Nuts, bolts, washers, couplers</td>
<td>-</td>
<td>Alloy steel, stainless steel</td>
</tr>
</tbody>
</table>
APPENDIX H – MODELING

CAMSHAFT

No Solidworks models were made of the camshaft. I was going to create it completely in Solidworks and add on the modified timing lobes in order for us to 3D print it, but since we did not 3D print and we just used JB Weld, I did not make a model of it in Solidworks.