Modernizing gas-powered farm equipment with electric power

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Introduction

Tilling devices are soil-preparation machines that efficiently loosen, aerate, and condition land before seeding. Tillers and cultivators are the two main devices that do this process of soil agitation but have their own special features that make them independent from one another. An article by Troy-Bilt provides a comprehensive overview of the difference between the two ("What's the Difference Between a Cultivator and a Tiller," n.d.). A cultivator is used for softer ground and plots of land that have already been developed. Tillers on the other hand are best used for hard ground and creating fields to be planted. They often have more aggressive tines and have higher horsepower motors compared to cultivators. When converting from gas to electric power it is important to understand how the horsepower and torque ratings convert between the two. A blog post on The Electric Chronicles offers a detailed explanation of this situation, also giving it in the context of a tiller (Dillard, 2010). The horsepower rating of a gas-powered motor isn't constant across its RPM range rather only reaches this peak at a specific RPM, this is where the powerband effect comes in, the given RPM range that a motor will reach its peak horsepower output. Electric motors, on the other hand, are not affected by powerband limitations to the same degree and can maintain a more consistent peak RPM. The purpose of this project is to design an electric powered tilling device using the body of a premanufactured gas-powered cultivator, while keeping performance levels similar to the gas cultivator.

Methods and Materials

This project was split up into three main parts. These parts being: completing the wiring for the cultivator's electrical system, designing and manufacturing the various parts for the electrical components, and testing the constructed cultivator to evaluate performance levels.

Figure 1 (left): This is the fully assembled electric powered cultivator. The two electrical components shown are the Club Car model EJ8-4001A regenerative electric motor and Curtis model 1515-5206 motor controller. All other parts are from the original gas-powered cultivator with the exception of the motor mount, shaft, and pully affixed to the shaft.

Methods and Materials (continued)

Wring was the first part of this project. The electrical system used for this project was from a Club Car golf cart. However, the motor and controller were taken from a 2022 model whereas the other peripherals were taken from a 1998 to 2002 model. This meant that schematics had to be cross referenced in order to make sure that each pin properly lined up between the controller and peripherals. Four 12-volt batteries were taken from a GEM electric golf cart and used to create the required 48-volt electrical power source.

The second part of the project was mounting the electrical system to the cultivator. A mount for the electric motor and throttle device was designed in Autodesk Fusion. The electric motor mount was designed out of sheet metal and is shown in Figure 2. The shaft was made out of a bar steel metal rod with two key slots to fit into the splined connector. The throttle system was designed out of laser cut wood parts and 3D printed ABS plastic.

The third part of the project was the actual testing. It consisted of one category and four measured sections. This being the measured RPM of the front tines under no load at various throttle percentages. Choosing to use four 25% increments as a way to analyze performance across the entire throttle range.

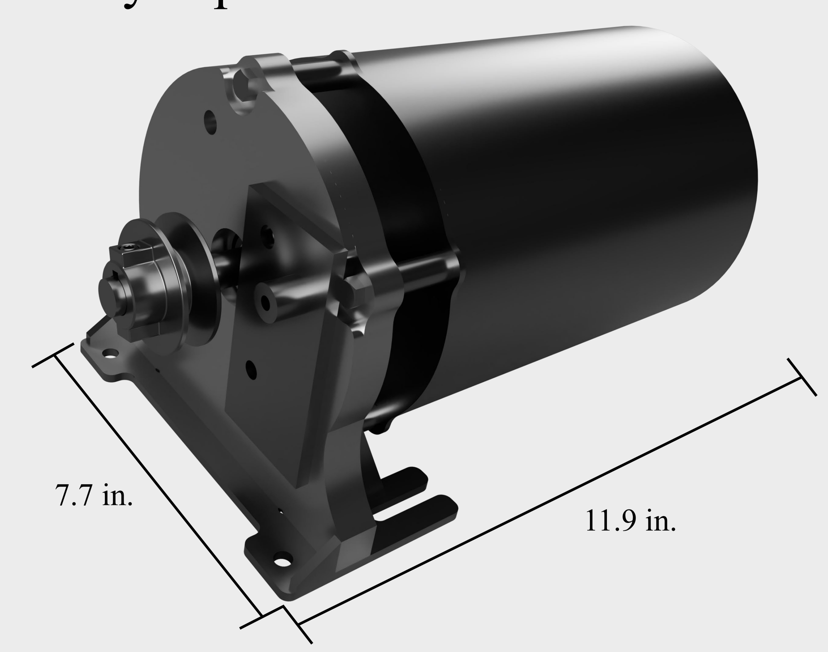
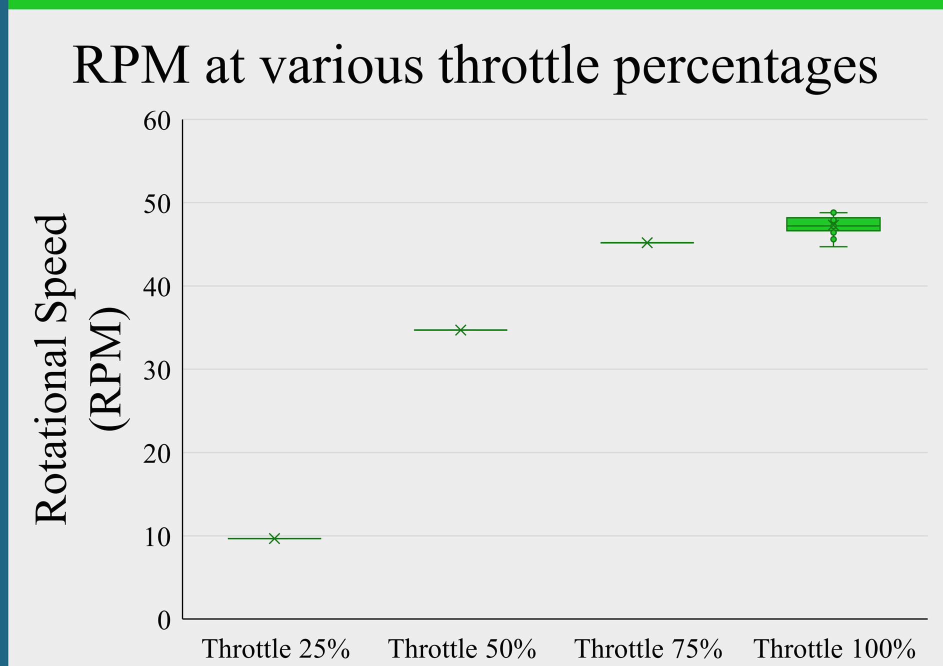


Figure 2 (right): This is a render of the motor mount with the motor itself along with the tensioner plate and pully. The vertical face was made out of 3/16-inch sheet metal and the shaft going through the middle was made out of 5/8-inch bar steel rod. The metal sheets were welded together along with the bottom mounting plate that has holes that align with the mounting spots on the gas cultivator.

Results



Graph 1 (left): This graph shows that measured RPM values of the front tines at 25% throttle increments: 25%, 50%, 75%, and 100%. At 100% throttle the individual points are tightly packed with very little deviation as expected when measuring RPM values, this indicates consistency. The trend of the data between the throttle percentages is non-linear.

Results (continued)

Data was collected on the RPM values measured at the cultivator's front tines under no-load conditions. A one-sample t-test was run at the 100% throttle level and compared to the original maximum RPM of the cultivator which is 155. The electric motor's RPM at the front tines (M = 47.3, SD = 1.1) was significantly different from that of the gas motor's RPM at the front tines, $t(19) = -448.22$, $p < .001$. This indicates a difference in performance levels between the gas and electric powered cultivator, with the maximum RPM of the electric powered cultivator being much lower than the maximum of the original gas-powered device. This difference shows that the RPM output of the electric motor is less than the original gas motor. However, both motors have the same power output, showing the difference in RPM does not indicate a lack of tilling power but rather an increased duration for the time it takes to till.

Conclusion

The purpose of this project was achieved by modernizing a gas-powered tilling device using the electrical system of a golf cart and the body of a gas-powered cultivator. Performance levels were shown to be different, with the mean RPM of the front tines under electric power being approximately 70% less than the maximum rated RPM of the original gas-powered cultivator. Reducing this discrepancy can be achieved by adjusting the gear ratios and pully sizes so, the output speed at the front tines is closer to the original RPM. However, this is only one out of many measurements that can identify the overall performance level of a cultivator. The same steps taken in this project might not apply to all premanufactured gas cultivators as each one has their own type of design and power requirements. This project can be an indicator to show how old farm equipment can be modernized with electric power through the use of readily available components; helping reduce material waste. Future research can be done by applying these principles to other farm equipment.

References

Dillard, T. (2010, October 9). *Electric gardener- Converting the tiller*. The Electric Chronicles. https://evmc2.wordpress.com/2010/10/09/the-electric-gardener-converting-the-tiller/

Troy-Bilt. (n.d.). *What's the difference between a cultivator and a tiller*. https://www.troybilt.com/en_US/knowledge-tb-choose-tiller-or-cultivator.html?srsltid=AfmBOoq4Z9C9uQqYCfV4aRSOird8XfLzoKluh5LdYpsWNf9EvXqnEhsQ