Designing a Low-cost, Light-weight Electric Snowmobile

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Abstract

The Indiana University-Purdue University Indianapolis (IUPUI) Jaguar team is participating in the 2015 SAE Clean Snowmobile Challenge (CSC) with the aim of achieving a low-cost snowmobile that weigh less than 200 kg (441 lb). It will be re-engineered to be an environmental friendly snowmobile without compromising the towing capability and less noise. We are using the Phantom Snowmobile PD250LT (Figure 1) that is manufactured by FMC Motor Company and sold through out North America. The modified NetGain WarP 7 DC-series motor is connected directly to the sprocket shaft using a Goodyear Synchronous Belt. The belt itself is very quiet and can produce less than 59 dB.

Figure 1. FMC Motor Company's PD250LT. Manufactured in Suzhow, China. It is sold in North America as the Phantom Snowmobile.

Introduction & Overview

This is the 11th competition where SAE International Clean Snowmobile Challenge has a "Zero-Emissions" category. Global climate change brings the urge to produce more efficient power generation engines, which could result in turning to alternative energy that has higher efficiency, and fewer pollutants. To this day, there are many hybrid cars being produced. However, the automotive industry is not the only one that needs to be geared towards alternative energy. Recreational vehicle industry accounts for its fair share of emissions. Hence, it drives our team to design an affordable electric snowmobile due to fragile environment on the Greenland Ice Cap. Since it is highly sensitive to chemical and human's byproduct, the researchers that are located in the Summit Station require special mode of transportation to and from their research sites.

Overall Performance

Certain aspects will be focused to ensure the effectiveness of this design. We believe we have chosen the lightest and smallest snowmobile available. The snowmobile was sold to us as a glider (without the gasoline engine). The initial weight of the sled was 112 kg (247 lb). After the additional electrical components being added, the machine weighs 200kg (441 lb). To achieve the goal of producing a quiet snowmobile, we used the quietest synchronous belt available, Goodyear's Eagle NRG. Also, we designed, with the assistance of International Engineering & Manufacturing (Woody's) a carbide insert for the skis. It consists of 2" carbide in the front and 4" in the rear. We also added 45 studs on the 110" long track. This will help the snowmobile ability to pull.

Team Strategy

The team believes that the re-engineered snowmobile will be competitive at the competition. Meeting all the requirements in the SAE CSC rules will not be taken lightly and is our major operation. We want to create a zero-emission and energy efficient snowmobile that is lightweight and affordable to the consumers. Hence, we managed to use the Battery Management System (BMS) to simplify the structure yet low in cost. When looking into buying snowmobile, users tend to look at their cost and range. We believe, this model will satisfy their needs.

Technical Details

Competing against other senior teams is a daunting task. The Phantom snowmobile helps the team a lot in achieving the lightest sled. The frame has many steel parts, as shown in frame is constructed using aluminum, it will be much lighter. This is our future idea and can be completed in later phases.

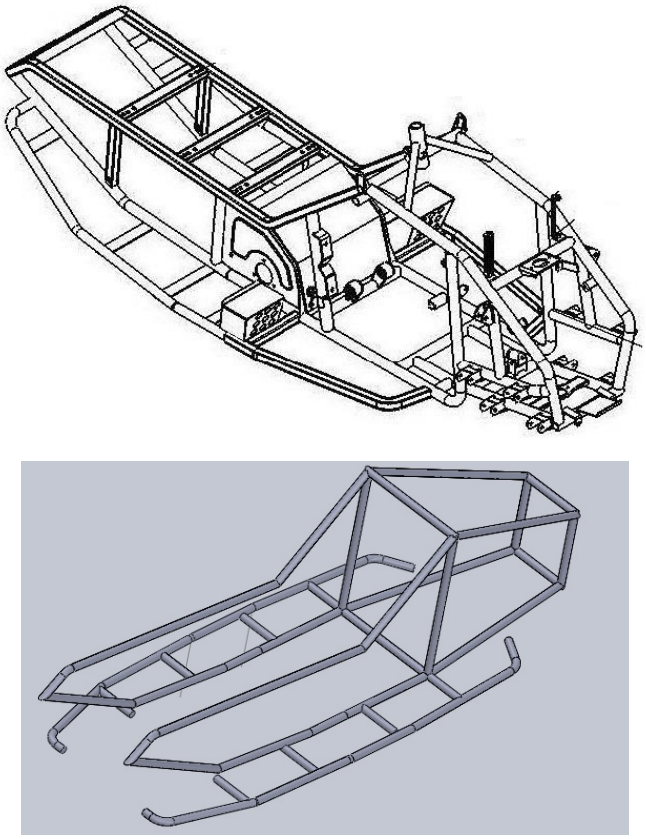

Figure 2. The structure of the PD250LT is composed of a steel frame (top). A further study is required to make the frame out of aluminum (bottom).

Range

Priority has been put so much into the range event. Most users are interested in how far and how fast and electric snowmobile can perform. The outlook of CSC is that the snowmobile should be able to drive at least 16 km (10 miles) at the speed of 32 km/h (20 mi/h).

Team Strategy and Technical Details

This year, we planned to create a safe snowmobile without the need or paralleling any battery cells. Hence the reasoning behind the decision of following half the amount requested in the Design Paper scoring sheet.

The battery configuration is to utilize 24 A123 LiFePO4 cells. There will be one series string of 24 cells. Each cell has a nominal voltage of 3.3 and has 20 Amp hrs (Figure 3). In addition to that, we used Delta-Q QuiQ battery charger that is connected to the BMS to tell the charger to turn on or off.

Figure 2 (the snowmobile frame). It is composed of round tube and square and weighs 27.2 kg (60 lb). We believe if the

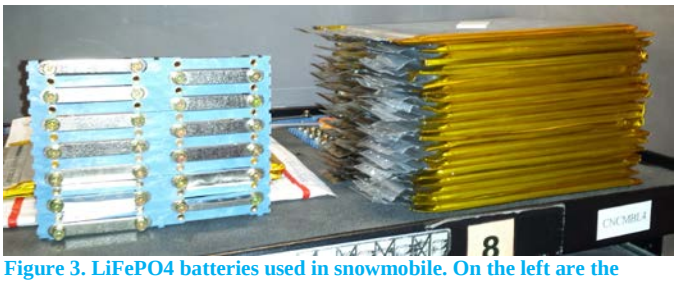

Figure 3. LiFePO4 batteries used in snowmobile. On the left are the mechanical tabs used to connect the cells into a pack. On the right are the A123 LiFePO4 battery cells.

The conversion of the snowmobile was completed by removing the gasoline engine, the fuel tank, the muffler, and other associated parts. These are replaced with a Net Gain WarP 7 DC series motor, a ReVolt Motor Controller, 24 cell LiFePO4, a Good Year Synchronous Belt (W-896), a 60-tooth bottom gear (W-60S) and 26-tooth top gear (W-26S) top gear.

We increased the range by increasing the drive train efficiency. The original snowmobile CVT is not efficient for an electric snowmobile. We can vary the speed of the electric motor allowing for different operating speeds. Keeping the CVT can cause a decrease of performance by 20 %. Removal of the chain case and jack shaft means that the snowmobile will require only two fluids: brake fluid and bearing grease. This makes a cleaner vehicle. It also reduces weight, and allows a simpler redesign.

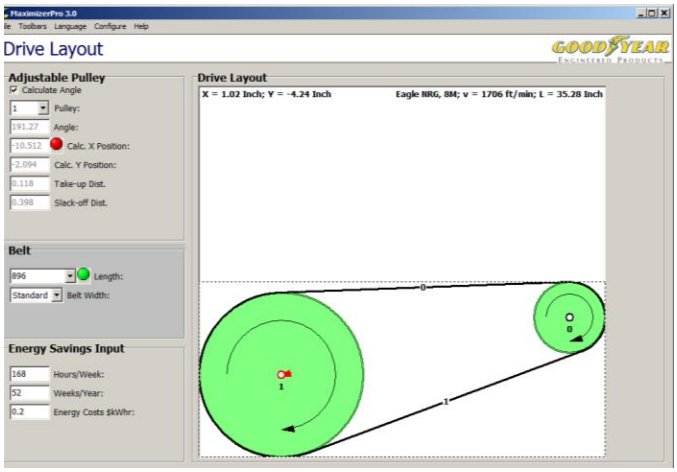

Figure 4. Screenshot of Good Year Veyance Technologies Maximizer Pro 3.0 software for belt selection. The team chose to pick available components. The gears in stock were made out of steel. Future refinements would allow alloy-type gears.

Table 2. Belt Selection

Option	Cost	Simplicity	Eff.	Noise
V-Belt	Low	Easy	Good	<60dB*
Gates Poly Chain	High	Medium	Best	73 dB
Goodyear Eagle	High	Difficult	Best	59 dB

There are three choices for belts which are the Standard V-Belt, and two synchronous belts: Gates Poly Chain or a Goodyear Eagle Synchronous belt. The Synchronous belts afford a better efficiency of 98 %, while the V-Belt slippage classified them with a 95 % rating. Synchronous belts also make 73 dB of noise whereas V-Belts have potential to be much quieter. The team decided to use the Good Year Eagle NRG (Table 2). Using Goodyear Veyance Technologies Maximizer Pro 3.0 software [3], the minimum gear diameter and belt type was chosen. In Figure 4, Maximizer Pro analysis tools will be used to calculate Eagle NRG Belt, and drive sizes. We set up the Maximizer Pro software with a load of 20 kW at 5 000 rev/min with a safety factor of 1.7. The safety factor is about double what our system is capable of preforming. This gives us a margin of safety for the drive system. Using the software we went with one of the lightest systems available.

Draw Bar Pull Capabilities

The PD250LT is the Long Track version of the 250cc lineup at FMC Motor Co. The track is single-ply and is 279.4 cm (110 in) long by 27.9 cm (10 in) wide. This small belt is powered by a DC motor.

Figure 5. Goodyear Eagle NRG Syncho system mounted on the Snowmobile. The WarP7 motor is painted red on the right-hand side of the picture. The gear ratio takes advantage of running the motor at higher speeds. Some of the material in the stock bottom gear was removed for fabrication and weight purposes.

Team Strategy and Technical Details

Any changes or improvements done to the sled to improve drawbar pull will affect the performance in other event. A heavy snowmobile will achieve better traction, and can pull more. However, a heavier machine is not helpful for range, acceleration, noise and weight events. The limiting factor in this event would not be power, but traction. Hence, our team is using studs to increase performance

Results

Range test and drawbar pull test will be conducted this year at Perfect North Slopes, Indiana. We will test the snowmobile on an uneven terrain and hill slopes to test the range. Meanwhile, to test the snowmobile's performance in the drawbar pull the back end of the snowmobile was attached to the back end of a parked truck with a two sets of triple blocks and a fish scale. The expected results obtained from the experiment will allow us to identify efficiency of this snowmobile despite the changes that have been made. The highest measured force also will be recorded. The snowmobile with the addition of 45 studs and running a DC motor should be competitive in the drawbar pull category.

Snowmobile Features

The front suspension has independent A-arms, and aluminum body piggyback front shocks. The rear suspension is slide rear type. Overall length is 221.7 cm (87.3 in), overall width is 110.2 cm (43.4 in) and ski stance is 100.33 cm (39.5 in). Original dry weight was 159 kg (350 lb). New weight of the snowmobile is less than 200 kg (441 lb).

Modifications and Cost

Our snowmobile MSRP was $7999. A new Phantom LT retails for $5,299. Major costs are the DC motor (WarP 7), which adds $1200 to the MSRP. The tiny battery pack adds another $1050. Various electrical components and safety systems add even more to the MSRP. The team is satisfied with meeting this goal. The modifications done to the snowmobile makes the snowmobile heavier on the left side. This is because the motor needed to be shifted over, and could not be perfectly centered on the snowmobile. We moved the brake to the other side of the machine, which also adds to the imbalance. The original body panels are intact.

Durability

Our modifications to the snowmobile are durable. Some of the original FMC snowmobile parts require further study. The tunnel is aluminum sheet metal attached to the frame. It is painted black, which doesn't add any value to the sleds performance.

Energy efficiency

Inherently an electric snowmobile requires a lot of power. One of the best mileage a production IC snowmobile gets is 12.325 km/L (29 mi/gal), driving 46.67 km (29 mi) uses about 114 000 Btu of fossil fuel.

$$\frac{114\,000\ Btu}{46.67\ km} = 2443\,\frac{Btu}{km}$$

The electric snowmobile averaged 194 W•h/km (310 W•h/mi) total energy use, which includes charging the batteries.

$$194\ W \cdot \frac{h}{km} \times 3412\ \frac{Btu}{kW} \cdot h = 661.9\ \frac{Btu}{km}$$

So the electric snowmobile will use less Btu/km (2 443 vs. 661). However, the electricity is not efficiently generated. The worst-case scenario would be electricity from a coal fired power plant with an efficiency of 33 %. The fossil fuel input is 3 times the electrical power output, i.e. 3 x 661.9 Btu/km = 1 985 Btu/km. This number shows that an electric snowmobile is slightly more efficient than a production gasoline snowmobile. The fact that a typical electric vehicle still has a significantly shorter range demonstrates the large discrepancy in energy density from a gasoline-powered sled to an electric sled.

Safety

We abided by all the safety standards in the rules and the Electric Safety Form standards.

Rider comfort

The original seat was not modified. Some taller drivers will find the snowmobile not as comfortable to drive.

Summary/Conclusions

This is our first year at this competition. We are risk takers in not using a typical snowmobile made by the four major manufacturers. However, the use of the lightest snowmobile will produce a result never seen before in efficiency. This will show how the range can be improved. We can increase the size of the battery pack in future years. The MSRP of $7,999 should be enticing to some snowmobilers for specific purposes. Doubling the range would add an additional $1,000 to the MSRP.

References

1. 2015 Clean Snowmobile Zero Emissions (ZE) Challenge Rules. Accessed online at 11 Feb 2015 http://students.sae.org/cds/snowmobile/rules/2015csc_ze_rules.pdf

2. Wies, R. W., A. N. Agrawal, and R. A. Johnson, Hybrid Electric Power Systems: Modeling, Optimization, and Control, VDM Verlag, 2007.

3. Goodyear MaximizerPro software. Accessed online at 11 Feb 2015 http://www.goodyearep.com/ProductsDetail.aspx?id=2328_0

4. Golub, M., et al., "Design of an meaningful electric snuukuuq," CSC Tech Paper (Fairbanks) 2014. Accessed online at 11 Feb 2015 http://www.mtukrc.org/download/uaf-bb/uaf_bristol_bay_ze_design_paper_2014_.pdf

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Definitions/Abbreviations

CSC Clean Snowmobile Challenge

BMS Battery Management System