Design of an meaningful electric snuukuuq - Phase 1

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Abstract

The University of Alaska Fairbanks – Bristol Bay Campus electric snowmobile team is participating in the 2014 SAE Clean Snowmobile Challenge. Two major attributes of our design are an ultra-low-cost of $7999 MSRP and a weight of less than 200 kg (441 lb). We are using a FMC Motor Company snowmobile. It is sold in North America as a Phantom Snowmobile PD250LT (Figure 1). 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 produces less than 59 dB. The accumulator is configured to support a maximum of 176.4 V using one series string of Turnigy NanoTech “6S” 8 A•h lithium-ion polymer hybrid cells, which utilizes a gel electrolyte. The battery box contains a small 1.411 kW•h accumulator. Utilizing only 17% of the allowed competition storage capacity, the snowmobile has limited range. Depending on optimal snow conditions total range is approximately 8 km (5 mi) range at 32 km/h (20 mi/h).

Figure 1. FMC Motor Company’s PD150LT.

Introduction & Overview

This is the 10th competition where SAE International Clean Snowmobile Challenge has a “Zero-Emissions” category. The National Science Foundation (NSF) supports research in Polar Regions. These regions require vehicles that would not contaminate the fragile environments [1]. Making a cleaner vehicle is important, but local high energy costs in Alaska makes this project extra important to transportation consumers. Gasoline is a precious commodity in rural cities and villages across our state, many of which are not connected to a road system. The price of a gallon of gasoline in February 2014 is $7.07 in Dillingham, Alaska. The cost of gasoline can be as high as $10/gallon depending on how remote the village is. Fuel is shipped to Alaskan villages in the summer by barge when the rivers and other shipping lanes are ice free. In some areas, fuel needs to be flown in, increasing the price even more [2]. Our focus is to create a snowmobile to help reduce villagers’ energy consumption, but still maintain their way of life. Sustainable transportation consists of having systems that are viable and affordable. Efficient electric vehicles used as primary local transportation, powered by renewable energy such as geothermal, wind, and hydropower makes sense if those technologies are affordable and reliable. Alternative energy resources are abundant in rural Alaska but are currently under-utilized. However, there are many alternative energy projects completed and future plans are developing. This is our first year in this competition answering the question about making a viable product for any end-user including both the scientists and avid snowmobilers. The idea is to have a vehicle that is light and comfortable for the rider. Snowmobiles are an indispensable means of winter transportation in rural Alaska. While these machines are primarily used for recreation in the rest of the country, here they are an important tool that makes life in remote villages possible. Snowmobiles are therefore an ideal candidate for electric conversion.

Overall Performance

The team focused on a few goals to be competitive this year. These are illustrated by Table 1. We used the lightest and smallest snowmobile available. FMC Motor Company also was cooperative and sold the machine to our team as a glider (without the gasoline engine). FMC is very interested in the final prototype we design. The bare sled weighed 112 kg (247 lb), and after added additional electrical components the machine weighs 200 kg (441 lb). No carbide runners are compatible for the Phantom. However, Woody’s has made a carbide runner for us with 2” carbide in the front and 4” in the rear. Along with 45 studs on the 110” long track, this will help our snowmobiles ability to pull. Additionally, we used the quietest synchronous belt available, Goodyear’s Eagle NRG.

Table 1. UAF-BBC major competition goals

Category	Challenge Record	UAF-BBC Goal	UAF-BBC 2014 Test Data
Weight	219 kg (482 lb)	181 kg (400 lbs)	200 kg (441 lb)
Drawbar Pull	3.74 kN (841 lbf)	2.71 kN (610 lbf)	>2.64 kN (594 lbf)
Noise*	57 dB	60 dB	<60 dB
MSRP	$11.8K	$8K	$8K

*With studded track

Challenges of ZE Snowmobile

The challenges of this competition are many. In this competition we obtain points in subjective and objective events. The subjective events count for 405 points and the objective events are worth 545 points. Figure 2 shows the total points scored by the ZE teams for the last 5 years of the Challenge. Lines connected each year to make the changes more clear. Thanks to the organizers openness there is lots of data to analyze of these events. The team's challenge is to be able to score a decent amount of points this year.

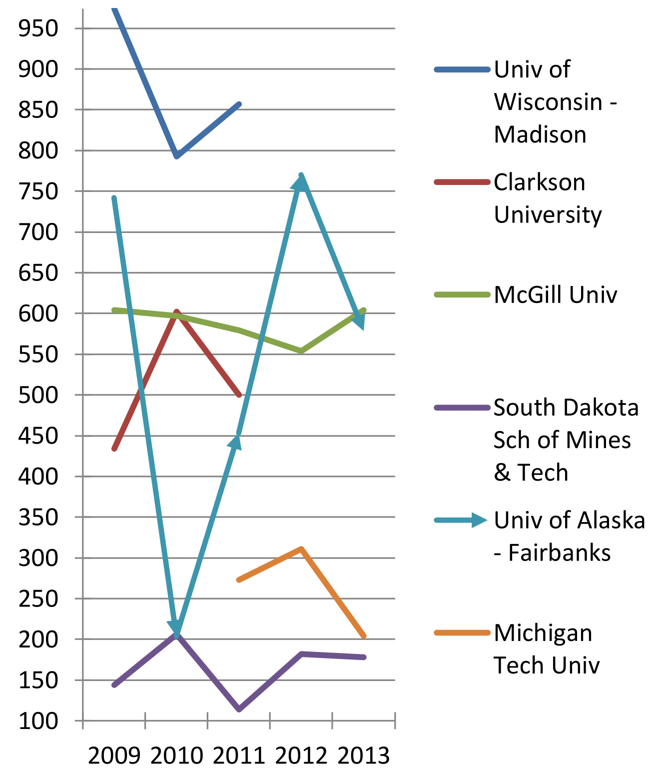

Figure 2. SAE 2009-2013 Clean Snowmobile Challenge results. Total point obtained is the y-axis and the years are on the x-axis. Data points are connected to show the extreme rise and fall of various teams. Normally data points would not be connected. It also shows relatively consistent scores by some schools.

Team Strategy

The team's goal was to produce a system that had impressive performance, while still being affordable and could be easily sold to the general public. The objective of the design strategy is to build a snowmobile that will be competitive at the competition. Meeting all the requirements in the SAE CSC rules was a major undertaking. Our main goal is to assemble the snowmobile in a simple yet effective way using low cost parts including the motor controller and Battery Management System (BMS), low cost but still durable. We want to create an energy efficient snowmobile that is lightweight and affordable for consumers. Most consumers buy snowmobiles depending on their cost and range, with this model we believe we will satisfy their needs. Whether it's for subsistence hunting and fishing, or going from point A to point B, we believe this product will get you where you need to go in an efficient and effective way.

Technical Details

This is Phase I of an enormous project. Competing against other legacy snowmobile teams is a daunting task. Our initial decision was to obtain the lightest sled available. We succeeded by obtaining the Phantom snowmobile. The frame has many steel parts. The snowmobile consists of a steel frame shown in figure 3. This frame is composed of square and round tube and weighs 27.2 kg (60 lb). Future plans are to construct the frame out of aluminum. Other weight savings ideas are emerging and can be completed in later phases.

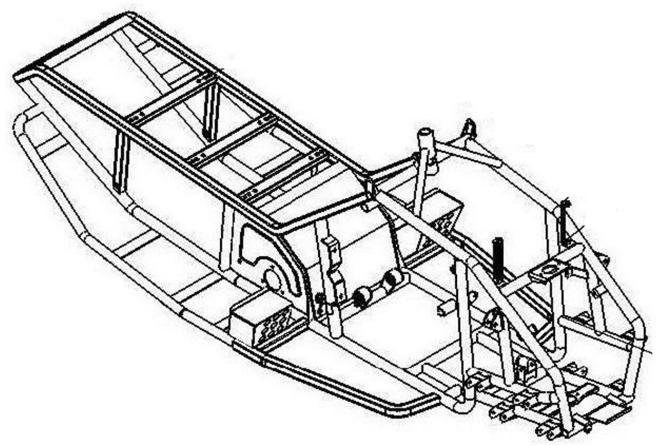

Figure 3. The structure of the PD250LT is composed of a steel frame.

Figure 4. The PD250LT contains 7 of the Turnigy Nano-tech 8.0 A•h battery. It has a mere160 Wh/kg. A battery with a higher specific energy will used next year to double the range.

Range

Range is the first objective event at the CSC. A huge emphasis is put on the range event. Most consumers are interested in how far and how fast an electric snowmobile can perform. The philosophy of the CSC is that the snowmobile should be able to drive at least 16 km (10 mi) at the 32 km/h (20 mi/h).

Range Team Strategy

This year we designed the snowmobile to do half that amount requested in the Design Paper scoring sheet. We decided that not meeting this minimum goal would be understandable if we explained out intentions. Our reasoning was to create a safe snowmobile without the need of paralleling any battery cells.

Also, the team wanted to put emphasis into creating a running machine capable of getting through Technical Inspection.

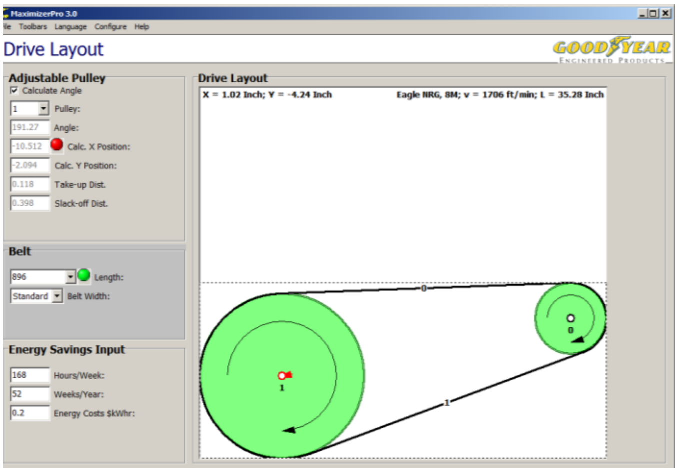

Figure 6. Screenshot of Good Year Veyance Technologies Maximizer Pro 3.0 software for belt selection.

Technical Details

The selection of the Turnigy battery cells gives the snowmobile a 160 Wh/kg of specific power (Figure 4). Batteries do exist that can double that power. The team hopes that after a successful event this year, better batteries can be obtained and be approved for use in future CSCs.

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, a 155.4 V battery, a Good Year Synchronous Belt (W-896), a 60-tooth bottom gear (W-60S) and 26-tooth top gear (W-60S) 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.

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

**At rated power*

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 (Table 2). 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 6, Maximizer Pro analysis tools were 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. Figure 7 shows the motor mounted to the Snowmobile.

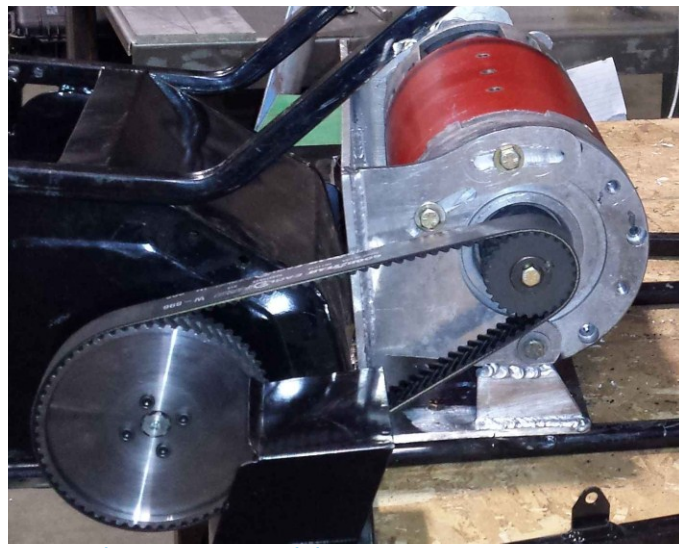

Figure 5. Goodyear Eagle NRG Syncho system mounted on the Snowmobile

Results

Range test was conducted in poor snow conditions this year in Dillingham, Alaska. We used a level and uneven terrain with no carbides or studs installed on the snowmobile. The machine traveled 6.4 km (4 mi) before we halted the test.

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.

Team Strategy and Technical Details

Improvements done to the sled to improve drawbar pull event are detrimental to performance in other events. 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. Our team is using studs to increase performance.

Results

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 highest measured force was recorded. During testing, the maximum recorded force pulled was 2.2 kN (500 lbf) At this point, the track lost traction and began to spin out. The consistency of the snow at the test site was icy snow melt. Loss of power was not a limiting factor during the test. Maximum pulling force can easily be improved with a different snow consistency.

For the last two years at the challenge the DC motor beat an AC motor in Draw Bar Pull [4]. The snowmobile with the addition of 45 studs and running a DC motor should be competitive in this category.

Snowmobile Features

The front suspension has independent A-arms, and aluminum body piggy-back 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 $1650 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.

Durable

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 efficient

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.

$$\frac{114\ 000\ \mathrm{Btu}}{46.67\ \mathrm{km}} = 2\ 443\ \frac{\mathrm{Btu}}{km}$$

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

$$194\ \mathrm{W} \bullet \frac{\mathrm{h}}{\mathrm{km}} \times 3\ 412 \frac{\mathrm{Btu}}{\mathrm{kW}} \bullet \mathrm{h} = 661.9\ \frac{Btu}{km}$$

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.

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Definitions/Abbreviations

CSC	Clean Snowmobile Challenge
BMS	Battery Management System