Zero Emission Electric Snowmobile Design Summary

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Abstract

Indiana University-Purdue University Indianapolis (IUPUI) has combined two groups of students of both the electrical background and the mechanical background to make leaps and bounds on the entry from 2016 and turn it into their entry for the SAE 2017 Clean Snowmobile Challenge. The main goals for this year's snowmobile are to not only pass technical inspection, but also make the first debut in the field events of the competition. In order to achieve the grand goals above the teams worked diligently to overcome major wiring problems, as well as working to reduce the overall weight, and some minor interference with the track.

Introduction

With the National Science Foundation (NSF) increasing research support in Polar Regions in the last 20 years, the impact of pollution has started to be taken into more serious consideration in these sensitive areas. Since the first "Zero-Emissions" Clean Snowmobile challenge in 2005 teams from all over have been competing at large-scale level to come up with the best design to eliminate the contamination from these vehicles and provide an efficient means of transportation for the research.

Project Overview

The IUPUI "Zero-Emissions" Snowmobile Team has consisted of a new group of students every semester since 2015 and is part of our Capstone Senior Design Class. Students from both the electrical and mechanical background are working side by side to improve the entry from 2016. The team has set new goals to improve upon the 2015-2016 design aspects. The goals include: reducing overall weight, improving capability, creating a new battery enclosure, passing technical inspection, and making a debut in the field events. Most of these objectives have already been achieved, or are currently in progress in hopes to finish up before the upcoming 2017 competition.

Mechanical Design Concept

Customer Requirements

To determine our customer requirements we looked at how each portion of the competition is scored, and determined what we found most important from that. Table 1 below illustrates the breakdown of each event and their respective scoring. In order to decide what events were most aligned with the consumer desires, the design team concentrated on the contests that pertained to the snowmobile execution and cost.

Zero Emissions Class Event	Minimum Points for Minimum Performance	Maximum Points for Relative Performance in Event
Engineering Design Paper	5	100
Manufacturer's Suggested Retail Price (MSRP)	2.5	50
Oral Presentation	5	100
Weight	0	100
Range	5	100
Draw Bar Pull	5	100
Acceleration + Load Event	2.5	50
Objective Handling and Drivability	2.5	50
Subjective Handling	2.5	50
Cold Start	2.5	50
Static Display	0	50
Objective Noise	3.75	75
Subjective Noise		75
No-Maintenance Bonus		100

Table 1: 2017 SAE Clean Snowmobile Challenge Event Scoring Rubric [1]

In the subcategories below we have broken up the aspects we focused closely on to achieve our goals in each of the snowmobile events.

Chassis

Figure 1: 2014 Polaris 550 Indy 144 Snowmobile base model [2]

IUPUI's 2016-2017 entry for the Clean Snowmobile is based off a 2014 Polaris 550 Indy 144 as seen in Figure 1. We chose this sled for many reasons, one being that we wanted a sled on the lighter end of the weight spectrum. This model provides us with a 15x144x1.35 width/length/height inch (0.38x3.66x0.034 meter) track, and an overall vehicle length and width of 124 inches (3.15m) by 48 inches (1.22m). This model gave us a rough dry weight of 429 pounds (194.5kg) with the internal combustion engine. [2] That was the weight before adding the electrical components and removing the internal combustion engine, after the additional components were added we estimated the weight to be roughly 500 pounds (226.8kg). The weight of this vehicle being on the lighter end of the spectrum we predict that this along with the track size will help us compete in a variety of snow conditions.

Range

The range event will be run at approximately 20 mph (8.94 m/s) and in order to prepare our snowmobile for this competition two main aspects were considered: weight and battery.

For the first characteristic, our team was able to reduce the weight of the snowmobile by around 30 lbs. (13.61kg) compared to the snowmobile used in the CSC 2016. This brings the weight of the snowmobile to less than 551 pounds (250 kg), which is fairly lightweight. The reduction was done by removing excess weight, specifically by replacing the heavy belt case with a lighter composite material. With this change the snowmobile has less mass to carry, which as a result improves its speed. Additionally, the team decided to avoid the use of studs this year in the snowmobile to further reduce its weight. This decision has its drawbacks since the studs would be beneficial for the draw bar pull event; however the team feels that the weight reduction gains will provide more benefits toward the overall competition.

Next, the other characteristic taken into consideration in this event was the battery. Our battery system has a total energy of 3.14 kW-hr (11.3MJ). Based on the capacity series of 32 Ah, the average voltage of 79.2 VDC and the total mass of the snowmobile and on the results from other teams in previous years our goal for the range that the snowmobile will achieve is of 18 km (11.18 miles).

Draw Bar Pull

A major event in the Zero Emissions Snowmobile Challenge is the draw bar pull. This event puts the durability and towing capability of the vehicle to the test. Both durability and towing are important aspects of a utility vehicle of any kind. Researchers traveling on these snowmobiles gathering their data and observing the remote areas will likely have to carry large amounts of equipment, not only to perform the job, but also for personal matters as well as safety precautions. Although IUPUI's design team has not had the opportunity to participate in the event in the past we have taken several steps in order to assure the best towing capacity will be optimized.

The team has looked at the rear suspension of the vehicle and has tested the shocks to ensure that they are in working order because suspension and the track play a large role in towing capability.

The 2014 Polaris 550 Indy 144 is equipped with a 15x144x1.35 inch (0.38x3.66x0.034 meter) track that has been pre-fabricated from the factory. However, our team changed the track to a 121x15x0.91 inch (3.07x0.38x0.023 meter). The length and width of the track contribute greatly to the amount of traction that the vehicle will have due to the distribution of weight on the large surface area.

Motor Selection

Having removed the internal combustion engine we were faced with the difficult decision of choosing between the use of an AC or DC motor. While the Warp9 DC motor was successful in the past, as of 2016 IUPUI had implemented an AC motor. In deciding if we would continue to use the AC motor a list of advantages and disadvantages was created.

Advantages
- Zero hydrocarbon emissions
- Reliability, minimal maintenance
- Easier to clean
- Length of run time for a given battery charge
- Length of driving range

Disadvantages
- More batteries required in series
- Cost of conversion

With the Electrical Engineering team being more familiar with the AC option and the advantages outweighing the disadvantages we decided again that was our best option. The familiarity is not the only reasoning behind the choice of the AC motor, it also weighs 50 pounds (22.68kg) less than the Warp9 DC motor used in the 2015 entry. The controller available for the motor limited the power from the AC motor to 80V. Although the limited power would also limit the torque of the snowmobile, we decided that this along with the weight we lost from switching from the DC to the AC motor could be an advantage in the range event by increasing our efficiency. AC motors have been rated 10% more efficient than the competitor DC motor in many cases; for this specific competition the AC motor should also allow a greater average speed which will be beneficial in multiple events.

Gearing

The sprocket selection uses a 3:1 ratio so that the AC motor can run at 3,000 rev/min and allow for 20 mi/hr (8.94m/s) optimum efficiency. Figure 2 shows the gear selection using the Maximizer software.

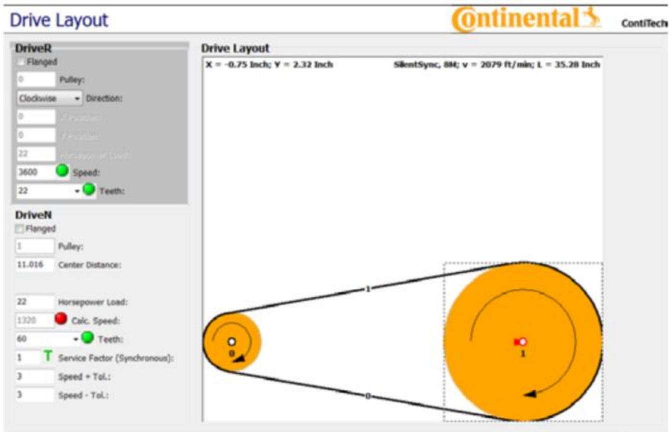

Figure 2: Continental Silent Sync Sprockets Drive Layout

Battery

The battery selected for the snowmobile is a MP320-049-HC-BO EnerDel battery module as seen in Figure 3. There are two units and each one has 120 VDC. The battery module has a nominal voltage of 69.58 VDC and a maximum nominal current of 250 A. In addition, it also has a maximum output current of 480A for ten seconds, and a maximum charging current of 160A. The whole battery system has 11.3 MJ of energy. Also, the battery module has 48 lithium-ion cells and a 12 Series – 2 Parallel cell configurations. EnerDel's lithium-ion cells are designed to provide integrated heat sinks between each cell for efficient heat removal and have robust packaging to protect the cells against physical damage and/or vibration hazards [3].

Figure 3: EnerDel's Battery Module

Battery Mounting System

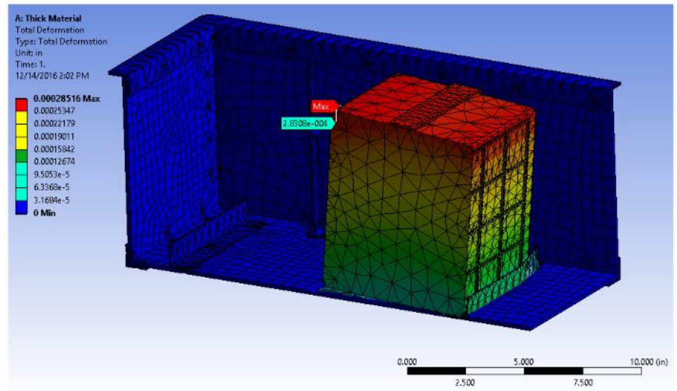

Figure 4: Ansys of applied horizontal force

According to the rules the battery mounting system has to be able to withstand a 20g (0.044 pounds) force in the horizontal direction. In order to test this requirement a simulation was created using the Ansys software. In the simulation an excessive force was applied to the face of the battery. The results, shown in Figure 4, demonstrate a small displacement of 3/10,000 inches (7.62µm) signifying that this design will satisfactory comply with the rule.

Battery Enclosure

The biggest modification made to the snowmobile was that the fuel tank and seat were removed and a new design was made for dual purposes, to serve as the seat and as the battery container. This design has a rectangular shape, uses the seat as the top of the containment vessel and is intended to hold four EnerDel Lithium Ion battery modules. Figure 5 illustrates the design for the battery enclosure.

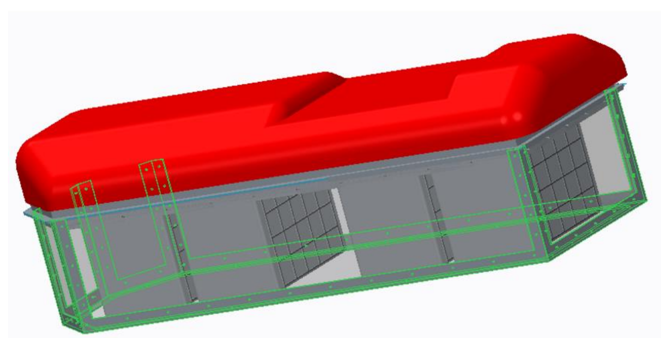

Figure 5: Battery enclosure design

The battery container is built out of panels made of Makrolon 3258 Polycarbonate that are structurally reinforced by 90-degree aluminum angles. The panels are attached to the frame structure by 1/8 inch (0.32cm) diameter steel bolts and a 5/16 inch (0.79 cm) thick rubber insulator covers the interior exposed head of the bolts. The aluminum mounting structure maintains a clearance gap of contact of a 1/8 inch (0.32cm). A dampening pad completely isolates the bottom bolt structures from contact to the snowmobile tunnel. Figure 6 shows the dampening pad used.

Figure 6: Polyethylene dampening pad

To comply with the rules of the competition the polycarbonate material serves as the electric insulator of the battery module system and it also helps to isolate the system from involuntarily energizing the snowmobile. This polycarbonate material also satisfies the UL94 compliance specification of flammability by having a thickness of 0.19 inch (4.76mm), which significantly exceeds the minimal thickness required by the rules. This extra thickness provides the snowmobile with a higher level of flammability. Figure 7 below demonstrates a side view of the battery enclosure/seat of the snowmobile.

Figure 7: Side view of the battery enclosure/seat

Tractive System Covers

Multiple components were relocated for ease of accessibility. In order to rearrange the set up 3D printed parts were created to serve as containment solutions for certain apparatuses. As stated in the rules all the parts of the tractive system have to be isolated by nonconductive materials or covers. Therefore, to comply with this rule the team created two covers, one for the 3-phase motor and one for the motor control unit, using 3D printing techniques and ABS plastic filament. Design illustrations for both covers can be seen in Figures 8 and 9. Advantage of using this material include that its lightweight therefore we are not adding extra weight to the snowmobile, its cheap, easy to maintain, and it fulfills the requirement of being nonconductive.

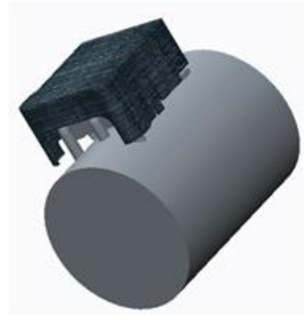

Figure 8: 3-Phase Motor cover

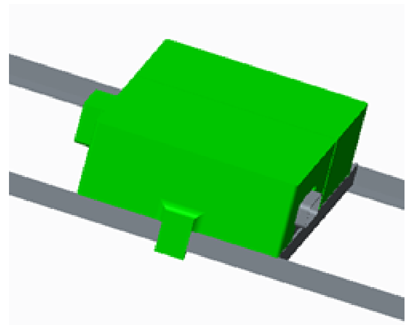

Figure 9: Motor Control Unit cover

Rider Comfort

Our new seat modification has completely changed the design of the original snowmobile seat since the team wanted to be able to include the battery container below it. However, rider comfort was always an important requirement that our group wanted to provide. In order to achieve this three inch padding was provide on the seat for seating comfortability and to successfully comply with the rules of the competition which require the seat to have at least one inch padding. In addition, the seat is long so that the rider is able to move to a position that is comfortable for them to reach the handlebars.

Conclusion

IUPUI's design team believes that the 2017 Zero Emission Snowmobile has the capacity to succeed in all the events of this year's SAE Clean Snowmobile Challenge. By focusing on major elements like the weight reduction, battery selection and new battery container design the team addressed the features that directly influence the snowmobile's performance on the competition. With these changes our team is expecting to be able to establish a baseline of results in order to further improve the snowmobile's design for future competitions.

References

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