Michigan Technological University's Innovations in Zero Emissions Snowmobile Technology

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Abstract

The Michigan Technological University (MTU) Clean Snowmobile Team is entering the 2017 SAE Internal Clean Snowmobile Challenge with a completely redesigned 2017 Polaris Indy 600 chassis. The snowmobile has been modified to operate on 100% electric power. In order to achieve a completely electric snowmobile, specific performance and safety concerns had to be met. The concerns addressed by the MTU Zero Emission Team includes the construction of the battery box, which will hold all the power sources and connections within one high voltage enclosure. The design of the battery box required isolating the from all dangerous electrical and thus avoiding all risks of injury. The box had to meet SAE specifications to ensure the rider's safety during the traditional operation and also during an impact event, such as a crash or rollover. The location and mounting for the electric drive system were selected and designed such that the snowmobile's overall ride and performance would not significantly differ from the stock design. The contents of this paper describe the design process in such a way to ensure all SAE specifications are in fact met.

Introduction

In order to perform research to understand past atmospheric conditions, the National Science Foundation (NSF) records data on the Greenland Ice Cap. The design for a Zero Emissions snowmobile has been highly sought after to allow measurements which are untainted by the researcher's vehicle. Research conducted on site, shows measurements of particles in parts per billion (PPB). A traditional snowmobile consists of a small internal combustion engine which releases emissions that have been generated during the burning of fossils fuels. These emissions can cause harm not only to the sensitive testing sites, but can also affect the results of the tests themselves. With this in mind, the challenge of having a safe and reliable alternative system was given to the world.

With the task being given, SAE developed a challenge to universities across the world to design and develop a fully electric snowmobile that would produce no emissions. Instead of having a tank which stores fuel, the teams would have to find a way to safely store electrical energy (batteries) on a snowmobile. Not only must the snowmobile be environmentally friendly, but it must be able to withstand the harsh winter conditions while still operating under the traditional operational stresses and vibrations which trails provide.

Overall Design

For 2017, the team at Michigan Technological University had the opportunity to build this chassis from the ground up. With the experience gained from the previous year's sled the team moved forward to make a fully operating snowmobile that would pass technical inspection. For the 2017 competition the MTU Zero Emission Team chose to build from a 2017 Polaris Indy 600 chassis as seen in figure 1. The main objective of 2017 was to produce a lighter and more reliable snowmobile that still complied with the SAE rules and regulations.

Figure 1. Stock Polaris Indy 600 [1]

Table 1. Primary Component Breakdown of the 2017 MTU Zero Emission Snowmobile

Component	Description
Chassis	2017 Polaris Indy 600
Engine	Parker GVM 142-75
Fuel System	Brammo 15/90 (Li-ion)
Drive Train	Drivers: OEM Yamaha Transmission: Brammo GVM 6-speed Drive: Direct Chain Drive
Suspension	Front Suspension: OEM Polaris control arms Rear Suspension: OEM Polaris
Track	Camoplast Ice Attack 121x15x1.063”

Battery Selection

The batteries chosen for 2017 are Brammo BPM15/90 Lithium Ion Battery Modules. Each module contains 45 individual cells, with real time temperature and voltage monitoring for safety. A total of six modules are used, with a total capacity of 7.94kWh to power the snowmobile. The batteries have a power density of 0.12 kWh/kg, making the

The batteries are charged using an Eltek Valere CAN controlled charger. The charger has a maximum output of 25A, giving the battery pack a theoretical charge time of under 4 Hours, depending on the state of battery charge and balance when charging is started.

Efficiency

Efficiency is a very important factor when it comes to producing an electric snowmobile. Having a snowmobile that lacks in the area of range, performance, and ride comfort will hamper the user often discouraging them not the use the product.

The efficiency of the snowmobile is related to both the mechanical and electrical component efficiency. Because the 2017 snowmobile is an all new design, the chassis was left in its stock configuration, with the focus of the design being on implementing the electrical drivetrain.

The theoretical electrical efficiency of the snowmobile was calculated for the least efficient case, which was determined to be at peak load (600A). The power output of the Traction system is 42kW, with the motor being 95% efficient, the motor controller being 90% efficient, and the rated resistance of components listed in table 2. The total power lost in the electrical system is a maximum of 7.62kW, making the electrical system a minimum of 84.6% efficient.

Table 2. Efficiency of Primary Components of the 2017 MTU Zero Emission Snowmobile

Component	Quantity	Resistance per unit	Power Loss (@600A)
Motor	1	N/A	2105 (W)
Controller	1	N/A	4912 (W)
3/0 Cable	5 (m)	0.203(mΩ/m)	365.4 (W)
High Voltage Contactors	2	0.2 (mΩ)	144 (W)
Maintenance Disconnects	5	0.05 (mΩ)	90 (W)

Battery Containment

Figure 2. MTU Zero Emission Battery Containment Unit

In order for the safe operations of the electric snowmobile, the system needs to isolate the driver from the high voltage system. The team had the challenge of constructing a container that would hold all the batteries and high voltage wiring while still being structurally sound enough for the rider to sit atop it. The container needed to be vented, non-conductive, and fire resistant per UL94-V0, FAR25, or an equivalent. The internals needed to be protected from moisture in forms of rain, puddles, and snow intrusion. On top of these restrictions the container would also need to withstand a 20g deceleration on the horizontal plane and a 10g deceleration on the vertical in order to satisfy the structural requirements.

In order to meet the requirements, the team selected to use Lexan Polycarbonate as the material of choice. The polycarbonate is not only UL94-V0 fire resistant, but also easy to work with, and clear, allowing for easy inspection of the components to ensure rules compliance, as well as easy diagnosing of potential issues without disassembly.

During the design phase of the battery containment, the team created several designs, all of which attempted to improve upon past team designs. The main task was to conveniently pack all the electrical components into one housing that could easily be disconnected, breaking all circuits within the container. Due to the increasing concern for a lightweight and versatile zero emissions snowmobile, the second objective of the battery box was to minimize the weight of the battery container. The components used in the battery box were weighed, and the final weight of the components used in the battery container are shown in table 3.

Table 3. Battery Container Component Weight

Component	Qty.	Weight: kg (lb)	Total Weight: kg (lb)
Batteries	6	10.4 (23.1)	62.4 (138.6)
Polycarbonate	1	26.3 (58)	26.3 (58)
Wires	1	3.12 (6.9)	3.12 (6.9)
Maintenance Disconnects	5	.63 (1.4)	3.17 (7)
BIR	2	.43 (.95)	.86 (1.9)
DC-DC Converter	1	.91 (2)	.91 (2)
Other	1	1.36 (3)	1.36 (3)
Total			98.1 (217.4)

The maintenance disconnects included on the battery container added approximately 10lbs of wire and components, however they make maintenance and repairs on the snowmobile easier and cheaper for OEMs and the end user. In addition, the technician or user would not be required to wear additional protective equipment which can be bulky and cumbersome, they can simply remove the maintenance disconnects and safely work on the machine. In order for the container to be attached to the tunnel, the team designed mounting holes in the base of the container that would mount directly into stock made slot in the extruded aluminum tunnel. The team used five ¼’’-20 Carriage Bolts in addition to five 1-½” wide 16-gauge sheet metal straps. The design behind using this is to add additional stability to the overall system by dispersing the force throughout the container rather than focusing strictly on the mounting bolts.

With the final shape designed and selected, the container had an FEA performed on it in order for the team to ensure that it would hold up to the additional stresses of a snowmobile’s daily operation. Maximum stresses occurred during the horizontal forces; however, the forces were well below the ultimate tensile stress by a factor of approximately eight, this can be seen in appendix

Battery Management System

For this new chassis the team has chosen to use Brammo 15/90 batteries. These lithium ion batteries provide many benefits to the current system, but none greater than the internal BMS system that is housed within every individual battery. The discussion was made to use this system rather than redesigning an in-house option, due to the fact the design was already tested and proven to be successful by Brammo in the use of their fully electric Empulse motorcycle.

The snowmobile communicates with the Battery Management System through a Brammo Battery Management Controller (BMC), The BMC communicates with the snowmobile over CANbus, and with the batteries over a serial connection. The individual battery modules are connected together through an RS485 multiple physical layer communication protocol; this allows each battery to send and receive information and commands with the BMC. The main information being read consists of battery voltage and temperature so that the battery complies within characteristics seen in table 4.

Table 4. Battery Management System Monitoring Characteristics

Component Range	Minimum	Maximum
Voltage [V]	11.6	15.95
Operation Temp. [C]	-10	40
Safe Storage Temp [C]	-40	60

Battery Charger

To recharge the accumulator, the zero-emission snowmobile will contain an onboard charging system. The Eltek Valere charger was selected due to the relative size and adaptability to our system. This system has a CAN-BUS communication feature which will allow it to communicate directly with the snowmobile system's batteries, BMS, BMC, Motor Controller, and Digital Display. This means the system will constantly be in communication when the system is energized. This feature is very innovative, as it will allow the user to see the conditions of batteries and the charging process through the dash along with any contingencies in the system that may occur during the charging process. In the case of any problems, the charger will automatically shut down and a "charge failure" will display on the dash unit. The charger has a maximum output of 25A, giving the battery pack a theoretical charge time of under 4 Hours, depending on the state of battery charge and balance when charging is started.

Shutdown Circuit

The shutdown circuit for the zero-emission snowmobile must include a kill switch, disconnect tether, master switch, key switch, insulation monitoring device (IMD), system interlocks, and a battery management system. The shutdown system is incorporated into a single low voltage circuit board, which controls the current driving the battery isolation relays. For 2017, all shutdown switches incorporated an open circuit fault to protect against broken wires or unplugged safety switches. If any shutdown system component returns less than 4V to the low voltage circuit board, the BIR's are opened and the voltage of the tractive system drops to under 60 V-DC. If the system were to be tripped by the BMS or the IMD, the circuit will temporarily disable the tractive system, and latch the fault in the circuit board. It will remain in this disabled state until the fault no longer persists, and the circuit board is manually reset. The system is designed in such a way that the rider cannot reset the system from the driving position, ensuring that a fault cannot be temporarily overridden, increasing the safety of the rider and protection of sensitive electrical components. A diagram of the concept behind the Low Voltage Circuit board is shown in figure 3.

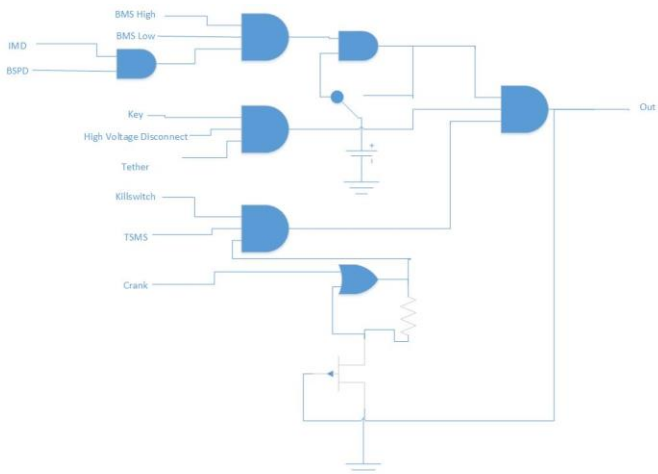

Figure 3. Snowmobile Run Condition Concept.

Motor Controller

Due to safety, isolation, and full range of programmability, a Curtis 1239E motor controller, seen in figure 4, was chosen for the 2017 Zero emissions snowmobile. The 1239E is based off from the Curtis 1238 architecture, originally designed to handle hydraulic pumps or on-vehicle traction drive, but incorporates isolated low voltage control and a higher degree of programmability. The 1239E fit the needs of the fully electric snowmobile in that it is designed to control both performance and power in an efficient manner.

Figure 4. Curtis 1239E Motor Controller

The motor controller mount was designed to fit along the belly of the snowmobile. It angles the motor controller slightly to allow for easier bending of our 3/0 high voltage wire used in the connections leading from the battery container to the motor controller and from the motor controller to the motor. The mount was made from a single sheet of ⅛” AISI 4340 steel and then bent to shape. The mount is bolted to the belly of the snowmobile chassis and secured with hose clamps to a 1.25” diameter tube, located near the nose of the sled. The motor controller is estimated to be 20lbs, so an FEA was ran on the motor controller mount using a weight of 30lbs for the motor controller in order to make sure that the mount can withstand the extra weight of the added chill plate as well. FEA results for the deflection and stress can be seen below in Figures 5 and 6, respectively. The 30lbs of the motor controller was represented as a 0.28psi distributed load based on the area of the motor controller/mount. The maximum deflection was found to be 0.1463mm. The maximum von Mises stress was found to be 13.45 MPa. The yield strength of the material is 710 MPa.

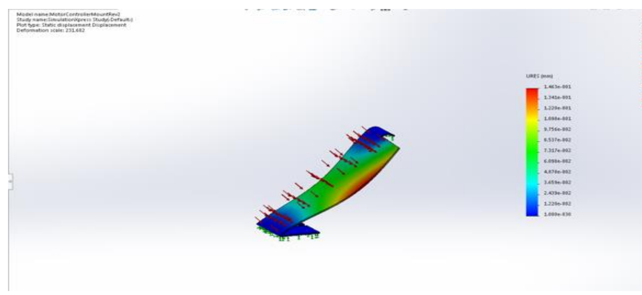

Figure 5. Deflection FEA Results on the Motor Controller Mount

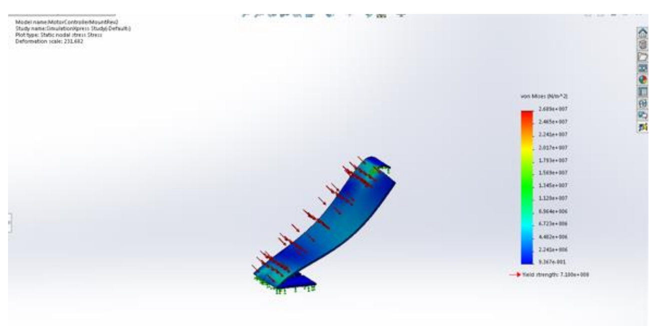

Figure 6. Stress FEA results on the Motor Controller Mount

High Voltage Fusing

To protect the rider, high voltage components, and high current wiring, fuses are included to prevent exceeding the safe current levels through all wires. The high power connections are made with 3/0 welding cable, with a maximum continuous current capacity of 365A. To protect the wire from overcurrent, a 350A busman removable fuse was added to the battery pack. This fuse is incorporated in the removable high voltage disconnect, and is easily accessible making fuse replacement, checking, and removal in the case of electrical issues. The fuse is also a slow-blow fuse, which allows the motor controller to draw a peak of 600A during heavy towing and acceleration, without blowing the fuse. Additionally, each battery module has an internally mounted 500A fuse to protect each battery module from over discharging due to a short circuit.

Digital Display System

For the 2017 Clean Snowmobile challenge, a Bosch DDU9 programmable display was added to the zero emissions snowmobile. The main functions of this display are to provide the rider with real-time status of electrical components, as well as the sled's performance. using a programmable display over a stock display gives us the opportunity to add a wide range of features that are not available through the stock setup, including unique graphics, pictures, and data within 12 freely configured display pages. This display also supports data logging, and has 3GB of built-in storage for recording data to use for making improvements to tuning, and performance. The display used is shown in figure 7.

Figure 7. Bosch DDU 9 Display

Cooling System

The team decided to run liquid cooling in this year's competition snowmobile. The decision was made after poor weather conditions during the 2016 competition resulted in the Curtis motor controller overheating with air cooling. The team this year will again be using the Curtis motor controller, however this time with the added benefit of a liquid-cooled chill plate to cool it. An aluminum chill plate with continuous copper tubing running through it was chosen as the best design, due to its high thermal conductivity and low chance of leak development. Figure 8 shows the finished chill plate with thermal paste applied. Thermal paste was used to improve the heat transfer between the motor controller and the chill plate. The heat exchangers, and the Brammo GVM traction motor could then be routed into the cooling system as the connections for the cooling system were already in place.

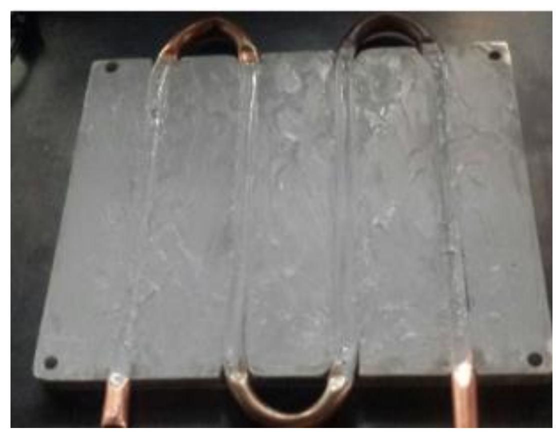

Figure 8. Chill Plate with Thermal Paste

The goal of the cooling plate was to establish a reliable cooling system and to make sure the Curtis motor controller does not reach the maximum motor temperature of 105 degrees Celsius (or 378.15 Kelvin). This is very important to ensure proper operation during competition, as well as making sure catastrophic failure does not happen to the motor controller or other components. To test this, a CAD model was created and an external flow analysis was done with the motor controller producing 4.55 kW of heat. The results of this testing showed that the motor controller will not reach the maximum operating temperature with the chill plate attached, as seen in Figure 9.

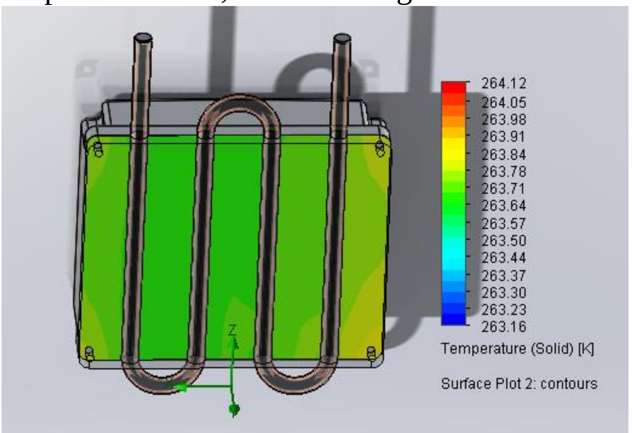

Figure 8. Curtis Motor Controller with Flow Analysis

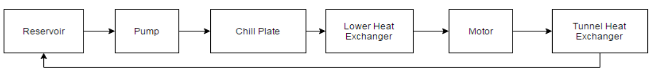

Figure 9. Cooling System Flow Chart

A three gallon per minute pump was chosen via motor cooling specifications. The cooling system will be running a 50-50 ethylene glycol/water mixture (universal antifreeze). A flow layout of the cooling system can be observed in figure 9 below. The lower heat exchanger and tunnel heat exchanger on our Indy 600 chassis were tested by observing the temperature drop in the coolant running through them. The lower heat exchanger was found to dissipate approximately 4.686 kW, while the upper heat exchanger was found to dissipate about 9.69 kW of heat energy. The motor can produce a maximum of 4.55 kW of heat, and continuously produces 1.25kW. Finally, figure 10 shows the motor controller and chill plate mounted in the chassis of the snowmobile and ready to be connected

Figure 10. Mounted Motor Controller

Motor Mount

A new motor mount and additional drivetrain parts were needed to be designed to adapt the Brammo motor and transmission to the Indy chassis. A properly designed motor mount is important to transmit power from the motor to the rest of the drivetrain without deflection due to the applied torque. The rigidity of the motor mount is important to maintain proper alignment of the drive system to maintain peak efficiency.

The team decided to use existing motor mount locations in the Indy chassis to maintain the structural integrity of the stock frame. In order to utilize the factory mounting locations, the rubber isolators were replaced with solid aluminum brackets to reduce deflection of the motor and transmission. Two aluminum plates were designed to mount the motor to the new motor mount brackets. The plates were designed using a replicated model of the motor and chassis CAD files. The plates were designed to keep the motor in the correct orientation to drive the stock jackshaft using sprockets and chain.

In addition to the motor mount, other driveline parts were fabricated to connect the motor to the driveline. The original secondary drive shaft of the Indy chassis is connected to the Brammo motor via a 530-sized chain and interchangeable sprocket. The team wanted to use as much of the original driveline parts as possible to take advantage of the gear reduction and structural rigidity of the chain case.

To complete the chain drive system, a chain tensioner and protective chain cover were fabricated to increase the safety and protect the rider from accidental explosions. This was done by taking measurements and dimensions of the area surrounding the chain and chain tensioner, and creating a CAD model of the chain cover to place into our model. The chain cover is attached to the snowmobile using two of the existing motor mount holes and one hole in the chassis.

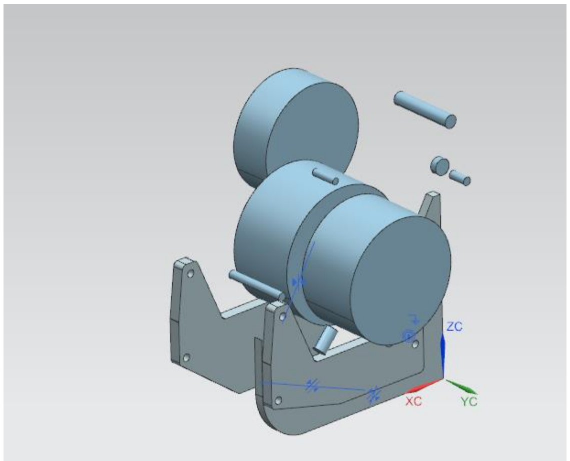

Figure 11. CAD Model Assembly of the Motor and Motor Mount Plate Showing all Geometry

After the design was completed, the chassis blocks were milled out of biller aluminum, while the motor mount plates and sheet metal for the chain cover were cut on a plasma table. The sprocket mounting sheave was machined from a stock secondary clutch bushing, with a 3/8” machined steel backing plate welded on, and refaced for roundness. The sprocket was then machined to fit the bushing and the bolt pattern of the face plate.

Figure 12. Physical Assembly of Fabricated Drivetrain System Including the Motor, Motor Mount, Chain Drive, and Tensioner

Validation of the motor mount design was done using FEA to determine the stresses and displacements of the motor mount plates during loading. To determine static load conditions, the motor weight (181.42 Newtons) was divided into four equal parts (45.4 N), applied to each of the four top parts of the two plates. The FEA results display that for motor weight load, the plates undergo a maximum displacement of 0.0024 millimeters, with minimal stress.

Under motor load, the team performed an FEA that included the torque of the motor. The team calculated that the two plates would experience a total torque of 74 Newton-meters. This value was then divided into two equal parts so that each plate would undergo a torque of 37 Newton-meters. Given this torque, the stresses and displacements of each plate were analyzed. The displacements of the plates are minimal, having a maximum of 0.00116 Newton per square meter. The two plates undergo very small amounts of stresses. Therefore, with our current design, the results show that the motor mount will not fail.

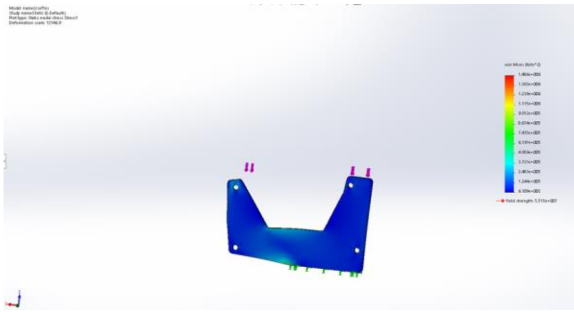

Figure 13. FEA Stress Results of Left Hand Side Motor Mount Plate Due to Motor Weight

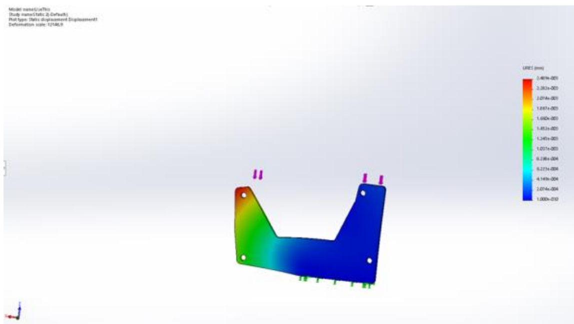

Figure 14. FEA Displacement Results of Left Hand Side Motor Mount Plate Due to Motor Weight

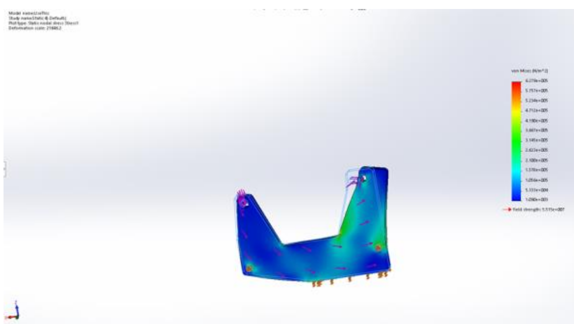

Figure 15. FEA Stress Results of Left Hand Side Motor Mount Plate Due to Motor Torque

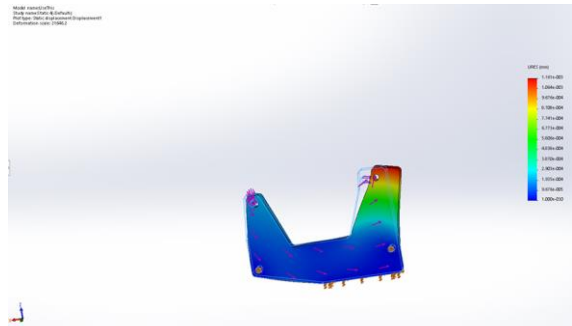

Figure 16. FEA Displacement Results of Left Hand Side Motor Mount Plate Due to Motor Torque

Drive System

The Michigan Tech Zero Emissions team is running a Brammo GVM Traction motor and transmission in the Polaris Indy chassis. Table 5 shows important motor parameters, gearing specifications, and track/driver information used for calculating the ideal motor gearing. The chain case gearing was left at the stock specifications, with a 22-tooth jackshaft gear and a 40-tooth drive shaft gear. The best way to adjust the sled's performance to meet competition specifications was to change the sprocket that connects the transmission output to the jackshaft. The final decision was based on calculations seen in table 5, which led to the use of an 18-tooth gear for the rear sprocket.

Table 5. MTU Zero Emission Drivetrain Specifications

Motor Power (kW)	41 (55 hp)
Motor torque (N-m)	74 (54.58 Ft-lbs)
Primary Drive input teeth	35
Primary Drive output teeth	59
Primary Drive ratio (N:1)	1.69
Transmission output teeth	14
Rear sprocket teeth	18
Track width (in)	15
Track length (inches)	121
Radius of Drivers (m)	0.0905 (3.56 in)
Circ. of Drivers (m)	0.57 (22.38 in)

In order to decide what size gear to run for the rear sprocket, the driver rpm, jackshaft rpm, and output sprocket rpm ratios were calculated. The rpms were calculated for sled speeds between 20-50 mph, using 5 mph increments, and can be seen in Table 6. The rpms were then used to calculate what gear ratios were needed for the chain drive to achieve in each gear and to hit our desired speeds. Once the desired speed and transmission gear where found, back-calculations were made to decide the correct size rear sprocket to achieve the desired speed using the stock front 14 tooth sprocket. Table 7 which can viewed in the appendix shows the results of these calculations. Looking at the gear sizes in Table 7, it was found that an 18-tooth rear sprocket would give the best variety of performance from 20-50 mph. after sprocket size was determined, exact speeds obtained from each transmission gear were calculated. Table 8 shows the top speeds for each transmission gear, using the 18-tooth rear sprocket. The top speeds are shown with system efficiencies of both 100% and 85%. It is expected that performance will fall above the minimum calculated electrical efficiency of 84.6%.

Table 6. MTU Zero Emission RPM Breakdown at Different Speeds

mph	Driver RPM	Jackshaft RPM	Output Sprocket RPM
20	943.54	1715.5	2566.7
25	1179.4	2144.4	3142.9
30	1415.3	2573.3	3793.1
35	1651.2	3002.2	4481.5
40	1887.1	3431.0	5280.0
45	2123.0	3859.9	5789.5
50	2358.8	4288.8	6432.8

Table 7. Effects on Efficiency of an 18 Tooth Rear Sprocket

18 Tooth Rear Sprocket		
Trans. Gear	Top mph	Top mph
	100% Eff.	85% Eff.
1st	23.52	19.99
2nd	28.68	24.38
3rd	34.47	29.30
4th	40.70	34.60
5th	48.01	40.80
6th	52.14	44.32

Another important factor in many events at the SAE Clean Snowmobile competition is the torque that the sled can produce. Changing the gear ratio to increase torque helps in events such as the acceleration with load and the draw-bar pull. Since the torque plays an important factor, Table 9 shows the calculations for the torque transmitted through the system to the track and the force that gets transmitted from the drivers to the track.

Table 9. Effects on Efficiency of an 18 Tooth Rear Sprocket

Gear	input teeth	output teeth	ratio (N:1)	torque at driveshaft, N-m (ft-lb)	force from drivers to track, N (lbf)
1	14	30	2.14	624.9 (460.9)	6,905 (1552)
2	16	28	1.75	510.3 (376.4)	5,640 (1268)
3	20	29	1.45	422.8 (311.9)	4,673 (1050)
4	22	27	1.23	357.9 (264.0)	3,955 (889.1)
5	24	25	1.04	303.8 (224.0)	3,357 (754.7)
6	20	19	0.95	277.0 (204.3)	3,061 (688.2)

Cost

The estimated MSRP for the 2017 MTU Zero Emissions Indy 600 is estimated at $19281.01. The highest individual cost of the snowmobile would be chassis itself, but it must be mentioned that the battery pack unit including all the batteries carried the highest price. Although the cheaper options for items like batteries are available, the compatibility and benefits of CAN-BUS communication as described in previous sections were deemed worthy for the additional cost.

Summary/Conclusions

The 2017 MTU Zero Emissions snowmobile was designed to meet the demands of the NSF within the rules and regulations of SAE International Clean Snow competition. The implementation of the systems on the 2017 MTU Zero Emissions snowmobile have preserved experience of riding on a tradition snowmobile. The 2017 MTU Zero Emissions entry blends that experience with the new upcoming technologies of electric vehicles.

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Acknowledgments

Special thanks to all the following sponsors for making it possible for the 2017 MTU Zero Emissions snowmobile to enter competition.

- **Polaris**
- **Brammo**
- **TE**
- **Bosch**
- **Denso**
- **Ford**
- **GM**
- **FCA**
- **John Deere**
- **Milwaukee**
- **Nexteer**
- **Meritor**
- **Mitsubishi Electric**

Definitions/Abbreviations

MTU	Michigan Technological University
PPB	Parts Per Billion
NSF	National Science Foundation
Li-Ion	Lithium Ion
BMS	Battery Management System
BMC	Battery Motor Controller
IMD	Isolation Monitoring Device
GLV	Grounded Low Voltage
CAD	Computer Aided Design
FEA	Finite Element Analysis

Appendix

FEA of Battery Containment with 10/20g Forces

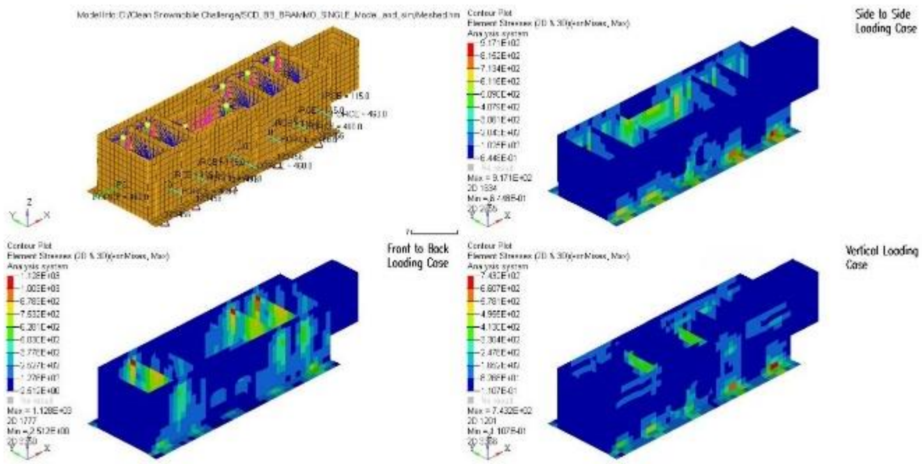

Table 8. MTU Zero Emission Gearing Ratio

Gear	Ratio 1st	Ratio 2nd	Ratio 3rd	Ratio 4th	Ratio 5th	Ratio 6th	Input Gear 1st	Input Gear 2nd	Input Gear 3rd	Input Gear 4th	Input Gear 5th	Input Gear 6th	mph
1st	1.50	1.83	2.21	2.61	3.08	3.37	20.95	25.65	30.95	36.57	43.09	47.25	20
2nd	1.20	1.47	1.77	2.09	2.46	2.70	16.76	20.52	24.76	29.26	34.47	37.80	25
3rd	1.00	1.22	1.47	1.74	2.05	2.25	13.96	17.10	20.64	24.38	28.73	31.50	30
4th	0.85	1.05	1.26	1.49	1.76	1.93	11.97	14.66	17.69	20.90	24.62	27.00	35
5th	0.75	0.92	1.11	1.31	1.54	1.69	10.47	12.82	15.48	18.29	21.54	23.62	40
6th	0.66	0.81	0.98	1.16	1.37	1.50	9.31	11.40	13.76	16.25	19.15	21.00	45
	0.60	0.73	0.88	1.04	1.23	1.35	8.38	10.26	12.38	14.63	17.24	18.90	50