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ABSTRACT

The 2006-2007 Clarkson University Electric Knights S.P.E.E.D. team has converted a 1999 Arctic Cat ZR 440 Sno-pro into a fully electric powered snowmobile. Major goals of the project were to allow the sled to be completely operational without any need for combustible fuel and allow the sled to perform tasks set forth by the SAE clean snowmobile competition standards.

To accomplish this, the Electric knights designed and built a fully operational electric snowmobile. This vehicle incorporates a 34 kW 3-phase AC induction motor that has a nominal speed of 12,000 rpm. The electric motor is connected to the primary variable clutch and is belted to a stock variable secondary clutch which is geared to the drive train and undercarriage. The vehicle is powered by 24 12V NiMH batteries which are wired in parallel and series to help with the discharge and charging sequences.

On-road tests conclude that the vehicle is must slower than a standard snowmobile with combustible fuel. With a top speed of approximately 30 MPH as well as dropped acceleration speeds, the sled is quite sluggish in comparison but makes up in intuition and marks a truly large step in pushing alternative fueled vehicles while helping the environment and reducing dependence on foreign oil.

INTRODUCTION

The Electric Knights set out to design an electric snowmobile, according to the design specifications that were set forth by the SAE Clean Snowmobile Competition. Our goal was to design and build an electric snowmobile, using an electric motor and controller that Clarkson University already owned. Design and battery selection was therefore centered around the 34kW 3-Phase AC induction motor and Universal Motor Controller (UMOC). We wanted to enter the SAE competition with a vehicle that eliminated the need for emissions at all, seeing this project as a stepping stone for the introduction of commercial electric snowmobiles. We believe that with the growing concern over the use and dependence of fossil fuels will encourage growth in the electric field, particularly in snowmobiles because of the immensely reduced noise and zero emissions, which make the recreational vehicle more suitable to the natural environments, such as National and State parks, where snowmobiling is prohibited due to these concerns.

ELECTRIC SNOWMOBILE DESIGN

BATTERY BOX

Exterior Design

The battery box is made out of a one-quarter inch thick aluminum base plate and corners with one-quarter inch thick Lexane. The purpose of this is to make a durable, but light weight battery box that keeps the weight of the batteries over the track and minimizes driver interference. These aluminum and Lexane pieces were then bolted together to form the box. The inside of the box was then sealed with silicone around the corners to make it air tight and the bolts were covered with spray on rubber to prevent conductivity. A piece of one-quarter inch thick plywood lines the bottom of the box to also prevent conductivity. Holes were drilled into the plywood to hold wooden dowels in place. The wooden dowels are used to separate the individual battery packs and to keep the packs firmly in place.

Interior Design

There are three layers to the battery box. The base layer contains ten individual battery packs. Another one-quarter inch piece of plywood separates the base layer from the middle layer. The middle layer is made up of ten individual battery packs also separated by dowels. A third piece of one-quarter inch plywood separates the middle layer from the top layer. The top layer contains 5 individual battery packs. The dowels are made up of four inch and nine inch pieces. All dowels are used to separate the packs and keep them firmly in close so that they don’t move while the sled is being operated. The four inch dowels are used to raise the layer of plywood slightly above the underlying battery packs. The nine inch dowels run from the base of the box to the top, through the pieces of plywood that separate the layers. This was done to stabilize the plywood to reduce movement.

<u>Venting the Battery Box</u>

In order to vent the battery box we used one-eighth inch plastic tubing that starts in the bottom of the box, exits the box through a small hole, passes through a small hole in the frame of the sled, and vents in an area around the track.

MOTOR MOUNT

<u>Design & Construction</u>

The motor mount is designed to be simple yet strong enough to incorporate the high revolutions and the angular momentum that the motor outputs. The three

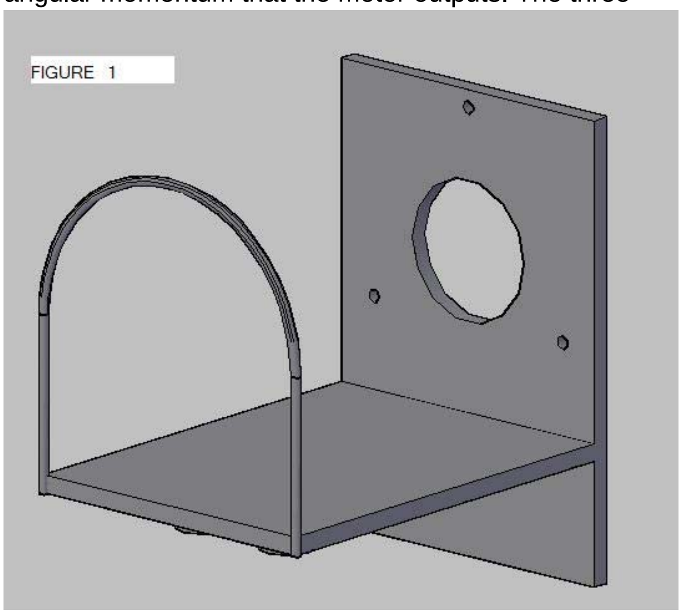


FIGURE 1

parts of the mount include the face plate, the base plate and the ¼” U bolt. Both plates are composed of 1/2” thick aircraft grade aluminum and the U bolt is steel (Figure 1). The face plate is attached to the front of the motor by 3 3/8” screws, with room to allow the pinion gear to extrude in the middle and attach to the primary clutch.

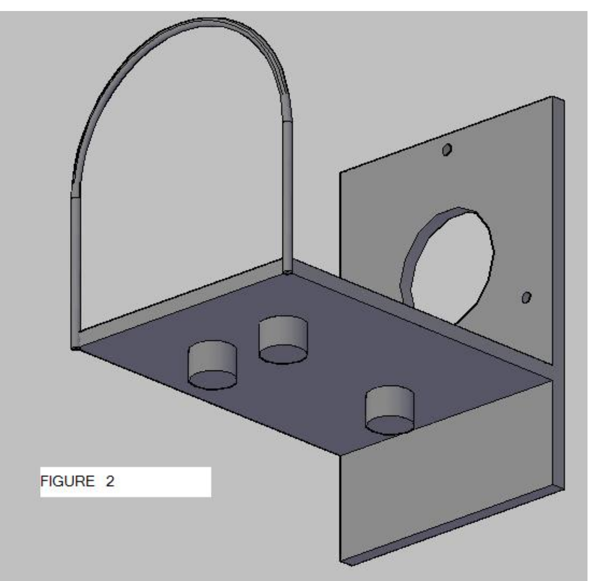


FIGURE 2

The rear of the motor is held down by a 9” U bolt which keeps any residual vibrations to a contained space.
On the underside (Figure 2) are three polyurethane cylindrical mounts, which connect the motor mount to the chassis of the snowmobile. This allows any external energy; vibration, bumps, etc from being transferred to the motor.

MOTOR CONTROLLER MOUNT

<u>Design</u>

The electric motor used in the design of our snowmobile requires a separate motor controller to run the motor and convert voltage. The controller needs a relatively low vibration mounting location in the snowmobile that allows for adequate airflow.

<u>Construction</u>

To mount the controller a plate was made that attaches to the frame of the snowmobile over the front ski area. The plate has the dimensions of 20”x 10” and is shown as figure 3. To mount the plate to the chassis three grade 8 bolts were attached through the plate onto the frame.

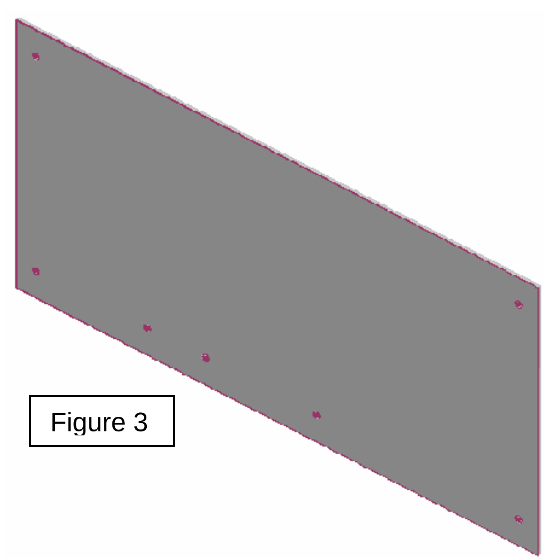
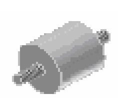


Figure 3

To attach the plate to the controller four rubber motor mounts (Figure 4) were used to act as shock absorbers as well as a firm mount. The motor mounts then attached to the controller on aluminum pieces built into the mount and bolted onto the plate. To make certain no harm to the motor mount would occur, front motor mounts were attached to a cross member of the front chassis and the motor controller cover.

Figure 4


POWER SOURCE

Battery Properties

The battery packs are made up of 10 Nickel-Metal Hydride, 12 volt 13 Amp-hour, cells. The packs are produced by Powerizer located in Richmond, CA. Each pack is rated at 12 volts and 13 Amp-hour. The batteries are rated to be fast charged at a 3.9 amps. The packs are rated with a highest discharge rate of 30amps for continuous running. Twenty-five of these batteries are used throughout the snowmobile.

Choice Rationalization

The reasons for using these batteries are the power supplied, weight, and cost of the batteries. In comparison to lead-acid, Ni-MH is more expensive, but has a lower weight per watt and do not build a memory. In comparison to lithium-ion, Ni-MH is heavier per watt, but are less expensive and safer.

Discharging

One battery is used to power lights and electrical parts of the motor controller; it will be regulated to be 12 volts for use of the motor controller. Two strings of 12 battery packs are strung together in series and the two sets are connected in parallel to produce 144 volts and 60 amps (max) while continuously running. The batteries while fully charged would be giving 182 volts and would be cut off when a voltage of 125 is reached to prevent the individual cells from going below 1.0 volts.

Choice Rationalization

The reason for this electrical set up is for the motor controller's specifications with the motor. The motor, manufactured by Solectria, AC21, is brushless and takes an alternating current. The motor controller, manufactured by Solectria, UMOC425T, has a minimum and maximum voltage rated at 120 volts and 192 volts, respectively. The motor is originally made for a car and was powered with only a continuous current of 70 amps. The motor controller will be programmed to not take more then 60 amps and it is believed that this will be enough to power the sled mechanically.

Charging

The single battery pack will be charged using a universal smart charger provided by Powerizer. Two methods for charging the other 24 batteries have been made, either charging the battery packs in parallel or series.

Parallel

Each string of batteries in series will be connected to relays that will allow the configuration to be changed by switches located safely for the operator. When switched the 12 batteries of one string will be changed from series to parallel. This will allow the use of a 13.4 volt 30 amp power source. Each battery pack would receive 13.4 volts and 2.5 amps at once and this will allow the batteries to be charged at a good pace and be equal in voltage. A downside to this method is that relay circuitry is complicated and costly. Two power sources will be used, one for each string.

Series

The batteries would be kept in the same configuration as discharging, with 2 strings of 12 batteries in series, connected in parallel. For this, a Solectria charger is used. It has a varying voltage and current output. It would be used at 144 volts and 6 amps, so each battery pack would receive 12 volts and 3 amps. This would allow the batteries to be charged quickly but would cause the batteries to not be equal in charge over multiple charges which can lead to the batteries not relieving a full charge and shortening the battery life.

SWITCHES

The switches work through the ignition box. The kill switch connected to the ignition box it allows the rider to turn off the ignition switch that turns on the motor controller. When the kill switch is pressed it basically interrupts the signal being sent to the motor controller telling it to run, stopping the motor controller.

Reverse Switch

The reverse switch also runs through the ignition box, when this switch is flipped the reverse circuit is closed sending a signal to the motor control. This signal, in turn, reverses the motor allowing it to propel the sled in a reverse direction.

Regeneration Switch

There will also be a switch to disable re-generation. The ignition box we have is equipped with re-generation which is always on by default, so a switch will be used to turn it off as we do not use this function.

Throttle

The throttle is controlled through the ignition box as well. A 5K variable resistor is used as a throttle. This allows us to control the speed of the motor by altering the current allowed to reach the motor.

Conclusion

Our electric snowmobile will be limited in range and speed because of the size of the motor and the amount of current that it will draw in order to run. It will, however, put out a tremendous amount of torque. We believe that this sled is an important stepping stone on the path to achieving an electric version of the internal combustion snowmobiles that are in use today. As battery technology and electric motor technology progress, electric snowmobiles will be able to compete on the same level, if not higher, as the current gas powered snowmobiles.