EVS29 Symposium
Montréal, Québec, Canada, June 19-22, 2016

Current Challenges and Outlook of Electric Snowmobile Technology - Lessons from Clean Snowmobile Challenge

Michael Golub, Jing Zhang

Department of Mechanical Engineering, Indiana University- Purdue University Indianapolis, Indianapolis, IN 46202, USA

migolub@iupui.edu

Summary

Although an electric snowmobile can be constructed, there are several technical challenges to make it viable for end-users. The energy requirements are extremely variable and depend on the weather conditions. Both temperature and snow conditions add to the complexity. The battery life will be shortened in extreme conditions. For example, the snow conditions cause changes to the rolling resistance as shown Figure 1. Current electric snowmobiles have not been able to use less than 200 Wh/mi. The snowmobile can be designed to take on energy denser batteries that will be developed eventually, however currently there is limited volume contained within the snowmobile to store the batteries.

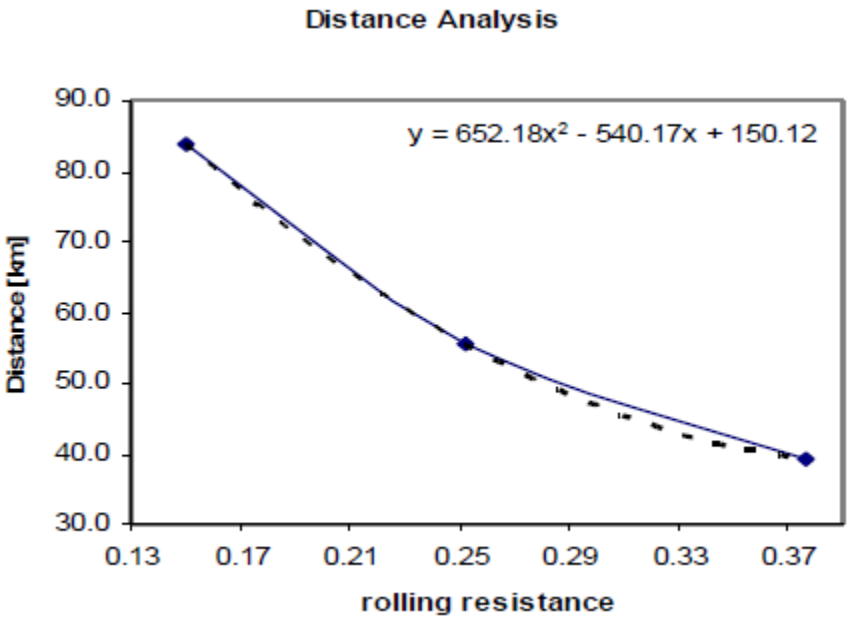


Figure 1 Effect of rolling resistance on range distance

1 Introduction

Electric snowmobiles produces zero-emissions when used locally. However, effective development of a commercially available snowmobile has not happened. Commercial snowmobiles do not exist because of the limited range and several performance issues. With better battery technology electric snowmobiles could more viable.

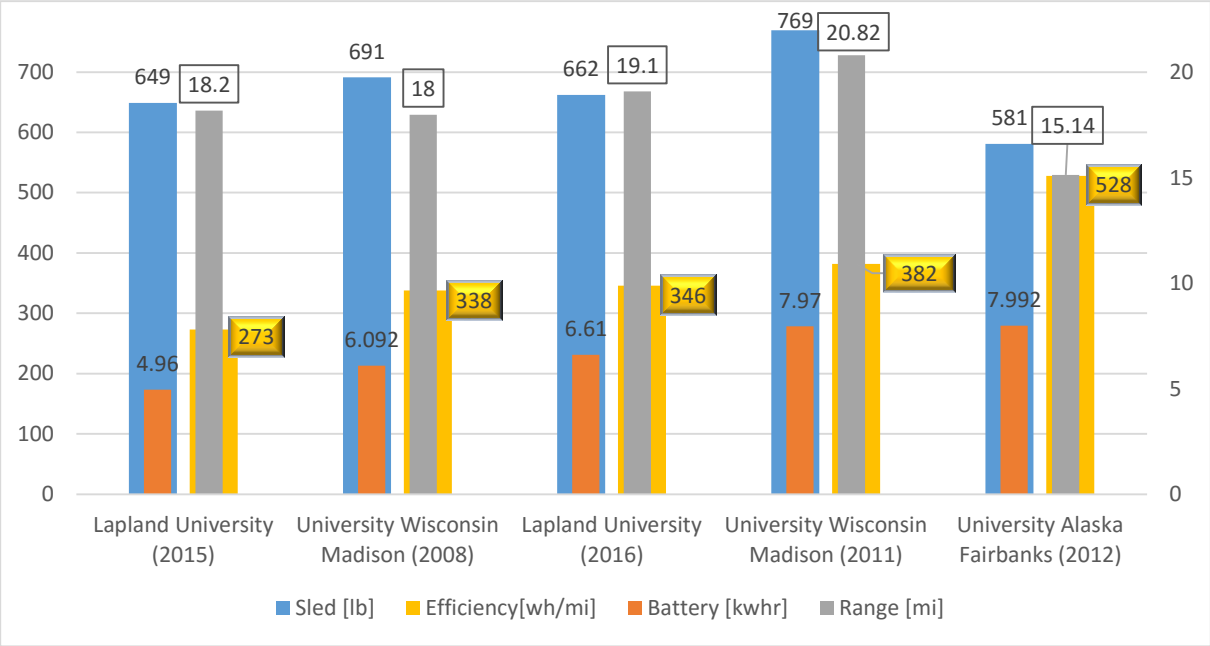
The Society of Automotive Engineers (SAE) has developed a robust series of academic competitions for engineering students. The SAE Clean Snowmobile Challenge® (CSC) is requires six competition days. The CSC allows university students to reengineer an existing snowmobile primarily to reduce emissions and noise. Their modified snowmobiles will compete in a variety of events including emissions, noise, fuel economy/endurance, acceleration, handling, static display, cold start and design. In 2005 the CSC added the additional category: "Zero-Emissions" in order to promote the use of vehicles which would not contaminate the fragile environments in these regions. The National Science Foundation (NSF) research in Polar Regions deals with sensitive areas that are highly impacted by pollution. Also, it was important to avoid contaminating samples taken from these areas, as engine fumes could adversely affect the samples. College teams are motivated to design affordable electric snowmobiles for several reasons: (1) the reduced cost of fuel, (2) to enhance the recreational rider's experience, and (3) assisting researchers to do sensitive research that cannot be swayed by pollutions.

Data collected at the CSC can be utilized to develop a better vehicle using the current technology. The data shows that snowmobiles at the SAE CSC have these attributes: (1) the range has been about 10 to 20 miles while using batteries smaller than 8KWhr; (2) the weight has ranged from 450 to 700 lbs; (3) the noise produced is 50dB to 70dB; (4) Either AC and DC motors are used; and (5) Motors are directly connected to the drive system as shown in Figure 2.

Figure 2 Two Continental Silent Sync pulleys and a belt are mounted on a Snowmobile.

This paper will discuss the results of the CSC and how the data can be used to forecast issues surrounding and potential solutions of the electric snowmobile technology. The SAE CSC has been a great success in giving engineering students an opportunity for real world projects.

2 Analysis



	Lapland University (2015)	University Wisconsin Madison (2008)	Lapland University (2016)	University Wisconsin Madison (2011)	University Alaska Fairbanks (2012)
Sled [lb]	649	691	662	769	581
Battery [kWhr]	4.96	6.092	6.61	7.97	7.992
Range [mi]	18.2	18	19.1	20.82	15.14
Efficiency[Wh/mi]	273	338	346	382	528

Figure 3: Comparison data (box graph and table) of several snowmobiles that did well at CSC from 2008 to 2016. Snowmobiles are driven at 20 mph

In this paper we do an analysis on snowmobiles that won first place and attempted to do 20 miles with an adequate sized battery pack. This is streamlined analysis where the focus is to look at the best watt-hour per mile [Wh/mi]. Lapland 2015 did the best at 273 Wh/mi and completed 18.2 miles. However, University Wisconsin Madison 2011 has the course record at 20.82 mi, with a snowmobile that weighs 120 pounds more and it shows that there efficiency of 382 Wh/mi is much higher. There are several takeaways from this data. One is that a snowmobile with a battery pack in the size of about 5 kWh to 8 kWh can about 20 miles. You can generally see a trend where lighter snowmobiles have better range.

Energy efficiency compared to emissions snowmobiles

The efficiency of an electric snowmobile can be compared to a standard production snowmobile. The mileage of a gasoline-powered snowmobile can be 29 mpg. Here we can use the driving distance of 29 miles uses 114 000 Btu of fossil fuel. This translates to 114 000 Btu / 46.67 km, which is 2 443 Btu of fossil fuels per km. The electric snowmobile that can average 250 Wh/km (400 Wh/mi) total energy use, which includes charging the batteries. Converting to British thermal units by multiplying 0.25 kW·h/km with 3 412 Btu/kW·h to obtain 853 Btu/km. Where the electricity comes from will provide a more accurate Btu comparison value. Using any type of alternative energy would alleviate the need for this comparison. One situation would be electricity

from coal plant with an efficiency of 33%. This would cause electrical power output to be three-fold, i.e. 3 x 853 Btu/km = 2 559 Btu/km. This number shows that an electric snowmobile is slightly less efficient than a production gasoline snowmobile. However, if a more efficient power generation is used such as a 45% efficient power plant, then 2.22 x 853 Btu/km = 1 893 Btu/km which is less than the original gasoline consumption. Nevertheless, a typical electric vehicle still has a considerably shorter range demonstrates the large discrepancy in energy density from a gasoline-powered sled to an electric sled. Also, the energy consumption is the same in either using gasoline or electricity to power a snowmobile, there are additional energy needs in order to bring that energy to a gas tank or a wall outlet. Argonne National Laboratory's The Greenhouse Gases, Regulated Emissions, and Energy Use in Transportation (GREET) Model can do a Fuel Cycle analysis, also known as "Well to Wheel" (or with snowmobiles "Well to Track."). This modeling software allows researchers to evaluate various vehicle and fuel combinations on a full fuel-cycle/vehicle-cycle basis. We used this modeling software to compare snowmobile combustion vs. electric snowmobiles. We estimated that an electric snowmobile operated with an 11 % reduction in CO_2 emissions and a 10 % reduction in Greenhouse Gases (GHG) based on energy generation in Fairbanks, AK (which is a good arctic-city example). The software will also give you modeling data on other emissions as well.

Conclusion

Current technology is available to make an electric snowmobile for a limited number of end-users. Further research is necessary to determine if enough needs exist to go into production. Future battery technology would make a snowmobile more attractive to other users. A simple 2-fold increase of kg/Wh in battery storage levels would double the range. However, if these more efficient batteries become available the snowmobile has limited storage space. Snowmobile designers would need to get more creative in where to store the battery packs.

Acknowledgments

This material is based upon work supported by the National Science Foundation under Grant No. 0808798. Any opinions, findings and conclusions or recommendations expressed in this material are those of the author(s) and do not necessarily reflect the views of the National Science Foundation (NSF).

References

[1] Auth, “Determining Hybrid Electric Snowmobile Feasibility Through Simulation”, M.S. Thesis, 2002.
[2] Golub, M., et al., "Design of a meaningful electric snuukuuq," CSC Tech Paper (University Alaska Fairbanks) 2014.
[3] Brodsky, E., et al., “Refinement of a High Efficiency Electric Drivetrain for a Zero Emissions Snowmobile," CSC Tech Paper (University Wisconsin Madison) 2009.