EVS30 Symposium
Stuttgart, Germany, October 9 - 11, 2017

Hybrid-Electric Snowmobile - Design and Development

Michael Golub, Jing Zhang

Department of Mechanical Engineering, Indiana University- Purdue University

Indianapolis, Indianapolis, IN 46202, USA

migolub@iupui.edu

Executive Summary

Snowmobiles use fossil fuels as their energy source. Snowmobile only use internal combustion engines (ICE). Successful hybrid-electric cars show that the application of hybrid-electric propulsion systems can work in the real-world. The hybrid-electric snowmobile viable design requires significant variations and modifications of current snowmobile designs.

1 Introduction

1.1 Snowmobiles available today derive their propulsion exclusively from either a 2-stroke or 4-stroke ICE. These current engines are dependable, fairly light and function well in the cold. Two-stroke engines, have a great power-to-weight ratio, but generate substantial quantities of pollution. Four stroke engines have become popular because of both fuel economy and reduction harmful emissions. Nowadays, both 4-strokes and 2-stokes co-exist in the snowmobile marketplace. Gasoline Internal Combustion Engines (ICE) are the norm, because diesel fuel has several drawbacks. Diesel engines are expensive and heavier than gasoline ICE. They also have several cold weather nuances. The major diesel advantage is that they produce more torque at lower rpm. This torque is essential to rapidly bring the track up to speed in wet and heavy snow [1].

1.2 Snowmobiles will continue to remain almost entirely dependent on fossil fuels as their primary energy source. No manufacturer produces a snowmobile that operates on anything other than a gasoline ICE. Some pure electric and hybrid designs exist from the occasional hobbyist, university research projects, and government-funded research [2-5].

1.3 Commercial success of hybrid-electric vehicles demonstrate that the implementation of hybrid-electric propulsion systems can be economically feasible. The hybrid-electric implementation into a snowmobile will be substantially dissimilar from that of a car. It will present many new engineering challenges and require major changes and modifications in its operation.

1.4 Battery technology has not improved enough for all-electric snowmobiles. The weight of the batteries makes the snowmobile loose it floating qualities. This restricts the total battery weight installed on the snowmobile. Current experimental electric snowmobile has ranges of 32 km (20 mi) at a speed of 32 kph (20 mph). The extreme cold will have some effect on battery capacity. Current plug-in charging infrastructure off the electric grid areas is non-existent. All-electric snowmobiles have advantages of quiet operation and zero emissions (when using renewable energy sources).

2 Design

2.1 The hybrid design requires an electric motor and an ICE. A small battery pack would drive the motor and a computer control system would allow the battery to be recharged while the gasoline engine was operating or when the braking system is engaged. The electric motor would potentially intensify the low-end torque and high-revolution power resulting in improved performance.

2.2 Three hybrid-electric powertrains that could be used are: parallel, series and combined models. Parallel allows the electric motor and ICE to function individually or work together if necessary. Series allows mechanical power production from an electric motor [1]. An ICE is connected to a generator, generating electricity which charges a battery and powers the motor connected to the drivetrain. This model has the disadvantage of losing energy in the transformation from mechanical energy to electrical energy and back to mechanical. The combined model is a combination of the parallel and series models.

2.3 For a reliable hybrid-electric snowmobile, a modified version of these three models would be best (see Figure 1). The ICE would remain connected to the powertrain via the traditional centripetal clutch used in all snowmobiles today. The electric motor would be connected in parallel to the drive shaft connecting the primary clutch to the chain case [4].

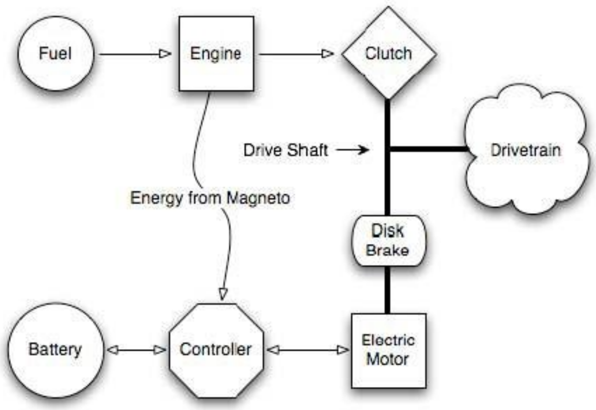


Figure 1: Hybrid Electric model to be used in a snowmobile [4].

3 Extended Range Electric Snowmobile Referencing

3.1 The Society of Automotive Engineers (SAE) has developed a robust series of academic competitions for engineering students. The SAE Clean Snowmobile Challenge® (CSC) 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. Future design progress on the electric snowmobile will be limited due to the discontinuance of the electric category at the CSC. Perhaps creative researchers will continue the effort [3,4,5].

3.2 Back in 2011 the CSC requested design papers for the Extended Range Electric Snowmobile (ERES) which is an electric snowmobile defined as a snowmobile meeting all the requirements of the Zero Emissions category and having a battery charger and gasoline generator.

3.3 The University of Alaska Fairbanks (UAF) base electric snowmobile was used as the base model for this design [6]. The snowmobile design used a hybrid-electric drive system by using the gasoline engine and electric generator. The proposed design used an electric Ski-Doo Renegade Sport 550F. This 250 kg (550 lb) machine is the same weight of the electric entry for the UAF for 2012. The snowmobile will have a lighter battery and smaller track reducing the weight by 22 kg (49 lb). This snowmobile will pass the range test of 32.19 km (20 mi) range at 32 km/h (20 mi/h) under optimal snow conditions. This snowmobile features a modified NetGain WarP 7 DC-series motor and is connected directly to the sprocket shaft using a Gates Poly Chain. The accumulator is configured to support 177.6 V using LiNiCo battery technology that performs at 200 Wh/kg. The battery box, containing the 8 kW•h accumulator is user removable.

3.4 Figure 1 shows the placement of the small generator. Table 1 shows how variable the final snowmobile weight will be using different batteries and generators. Most of these sleds configurations are acceptable and have the potential to allow for 32.19 km (20 mi) range. Further weight reduction can be done by using carbon fiber parts and lighter tracks. Use of carbon fiber affects the overall cost, so it needs to be a justifiable expense. Current battery technology is typically available with 200 Wh/kg battery. Three other densities are shown in Table 1.

Table 1: Snowmobile Possible Weights

		Battery Selected [Density[Wh/kg], total pack weight[kg]]			
		140 Wh/kg 57 kg	173 Wh/kg 46 kg	200 Wh/kg 40 kg	300 Wh/kg 26.7 kg
Generator Added	*None*	*250 kg* *(550 lb)*	*239 kg* *(527 lb)*	*233 kg* *(513 lb)*	*220 kg* *(484 lb)*
	20 kg, 1600 W	270 kg (595 lb)	259 kg (571 lb)	253 kg (557 lb)	240 kg (528 lb)
	90 kg, 8000 W	360 kg (793 lb)	349 kg (770 lb)	343 kg (756 lb)	330 kg (726 lb)

4 Extended Range Electric Snowmobile Results

4.1 The Yamaha EF2000 weighs 20 kg and does 1,600 W continuously. Meanwhile the Briggs and Stratton model 30210 weighs 90 kg and does 8,000 W continuously. These generators can be mounted onboard the snowmobile. They cannot produce enough to charge the batteries fully within 30 minutes. The Yamaha is estimated to allow for 5 km (3 mi), and the Briggs will do about 16 km (9.6 mi). These two generators were chosen for their efficiency. The Yamaha costs 842 € and the Briggs costs 1,275 € and are readily available.

4.2 To achieve the goal of driving 32 km and then recharging for 30 minutes and drive another 32 km, would require a larger generator. Using a 198 kg (450 lb) Generac GP1750E will cost 3,150 €. It can run continuously at 17,500 W. These would fully charge the pack in 30 minutes. Using a Manzanita Micro PFC75 battery charger increases the price by 3,850 €. The trailer to haul the generator would add additional costs. Northern Sled Works Siglin sled trailer is 850 €. Adding the best components will bring our Manufactures Suggested Retail Price (MSRP) to 21,999 €.

4.3 A recent design used a 7kWh battery pack and would give the snowmobile a 4.4 mile range when using strictly battery power [3]. The estimated production costs would make the snowmobiles cost 70,000 €. Meanwhile, the Canadian government used over 423,000 € to design a stealth hybrid snowmobile [2].

4.4 More design work is necessary to obtain less expensive and higher performance snowmobile. Current battery energy density will eventually be adequate for a snowmobile. When that happens current design plans can accommodate those batteries. Ultimately, current costs cannot justify selling these to the mass market [7].

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,” Masters thesis, University of Idaho, 2002.

[2] Blatchford, A., “Canadian Forces test ‘Loki,’ a stealth snowmobile for covert Arctic ops,” The Globe and Mail, August 18, 2013.

[3] Sandnes, M., “Konseptutredning av en elektrisk-hybrid snøscooter; Roskva Snow,” Master's thesis, Norwegian University of Life Sciences, 2017.

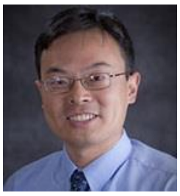
[4] Schroeder, E., Brodsky, E., Schumacher, A., & Bower, G. R., “Integration of Hybrid-Electric Strategy to Enhance Clean Snowmobile Performance,” (No. 2006-32-0048). SAE Technical Paper, 2006.

[5] Golub, M., Thompson, I. & Apperson, D. “Electric Hybrid Snowmobile Design,” UAF-ERES-001, SAE International, 2012.

[6] Golub, M., Thompson, I., et al., “Design of an affordable electric snowmobile — Done Right” Clean Snowmobile Challange Tech Paper (University of Alaska Fairbanks), 2012.

[7] Olson, L. E., Squires, J. R., Roberts, E. K., Miller, A. D., Ivan, J. S., & Hebblewhite, M. “Modeling large-scale winter recreation terrain selection with implications for recreation management and wildlife,” Applied Geography, 86, pp. 66-91, 2017.

Michael Golub is the Academic Laboratory Supervisor in the Mechanical Engineering Department at Indiana University – Purdue University Indianapolis (IUPUI). He is an associate faculty at the same school, and teaches part-time at two other colleges. He has conducted research related to Arctic Electric Vehicles. He participated and advised several student academic competition teams for several years. His team won 1st place in the 2012 SAE Clean Snowmobile Challenge. He holds an M.F.A. in Television Production, and both an M.S. and a B.S. in Mechanical Engineering, and a B.S. in Sustainable Energy.



Jing Zhang is the Associate Professor of Mechanical Engineering at Indiana University – Purdue University Indianapolis (IUPUI). His research area includes renewable energy, additive manufacturing, and multi-scale modeling. He is the faculty mentor of the IUPUI student team which won 1st place in the 2012 SAE Clean Snowmobile Challenge. He holds Ph.D. in materials science from Drexel University.