Re-Engineering a 2015 Polaris Indy for the Clean Snowmobile Challenge 2015

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Abstract

Northern Illinois University's (NIU) Clean Snowmobile team will compete with a re-engineered 2014 Polaris Indy 600 in the 2016 Clean Snowmobile Challenge. The snowmobile will retain its factory equipped two stroke engine. The team has met the competition objectives, to maintain or increase the snowmobile's performance while improving its exhaust noise and emissions. The stock Polaris engine control unit (ECU) was replaced with a Vi-PEC tunable ECU, coupled with a General Motors (GM) Flex Fuel sensor to accommodate a range of ethanol blend fuels. Other improvements were added to the snowmobile in order to improve safety and braking, reduce noise emissions, as well as improve fuel economy. These modifications were done to help facilitate user friendliness, cost effectiveness, and clean emissions in mind. The snowmobile was found to be a feasible option for recreational riders as well as performance oriented riders.

Introduction

The NIU Illinois Clean Snowmobile Team members all have a real passion for the sport. Growing up around snowmobiling and becoming aware of global issues has sparked the team's interest in the area of alternative fuels for use in snowmobiles and other recreational vehicles. The sheer fact that many snowmobiles in use today produce a high amount of chemical pollution has given rise to conversation, debate, and political action in many parts of the world. Often snowmobiling takes place in and around environmentally sensitive areas, such as state and national parks. By reducing the dependency of fossil fuels used in snowmobiles, we can reduce the carbon footprint that snowmobiling has created. This negative impact on the environment has created new objectives for college students [1].

The team began with a 2014 Polaris Indy 600 that met factory specifications. In accordance with competition rules, the first goal of the team was to modify the snowmobile to accommodate an ethanol fuel blend, for use at the competition.

The NIU team has the lofty goal of proving that a traditional two stroke engine is a viable option for this competition. In order to achieve this goal, NIU focused on fuel system modifications that could maintain the integrity of the engine, while also maintaining the performance worthy of the Polaris logo. To improve the overall safety of the machine, NIU also focused on improving the traction and braking systems. Modifications to the track and skid system were made in order to improve the fuel economy of the snowmobile. The improvements described herein can be an example for a vast majority of the snowmobiling community. When considering our design changes for the competition, consumer appeal has always been at the top of our list. The team's goal is to implement modifications to the snowmobile that can be a genuine contribution to the snowmobile community at large. By creating a cleaner snowmobile that meets the desires of snowmobile enthusiasts, the sport can have a bright and promising future.

Team Objectives

Reduce Exhaust Emissions

The NIU team has an objective of lowering the exhaust emissions. A five mode test will be conducted to verify that each snowmobile complies with the Yellow Stone National Park standard. Table 1 clearly identifies each mode and corresponding categories.

Table 1: Five Mode Emission Test Cycle

Mode	1	2	3	4	5
Speed %	**100**	**85**	**75**	**65**	**Idle**
Torque %	**100**	**51**	**33**	**19**	**0**
Wt. Factor, %	**12**	**27**	**25**	**31**	**5**

Test results will show the quantities of CO (carbon monoxide), HC (hydrocarbons), and NOx (nitrogen oxides). HC+NOx are not allowed to be greater than 90 g/KW-hr and CO must be lower than 275 g/Kw-hr [8].

$$E = \left[1 - \frac{(HC+NO_x)-15}{150}\right]*100 + \left[1 - \left(\frac{CO}{400}\right)\right]*100 \geq 100 \quad [1]$$

The quantities of each are use in the formula [1] to calculate the team's emission number, where the emission number (E) must exceed 175. The emission number for each team will be used to calculate their final score. The method of reducing the emissions will be with the use of fuel and ignition tuning of the snowmobiles ECU.

Fuel Economy

In addition to the emission test, the fuel economy and endurance of the snowmobile is an important team objective. The team's goal has been to make a system that can use ethanol blended gasoline. This blend ranges from a 0% to 85% mixture. This change in fuel requires a change in fuel mapping, which allows for a change in the fuel economy of the sled. The approach for accommodating the ethanol fuel was to replace the stock ECU with a Vi-PEC tunable ECU. A GM Flex Fuel sensor was also added to allow real-time compensation for the range of ethanol blend.

Each team will compete in an endurance event that will require the snowmobile to operate on a groomed trail for 100 miles. Every snowmobile will follow and maintain progress of the assigned trail judge. The trail judge can also disqualify a team from the event if the snowmobile does not maintain the steady pace of up to 45 mph. The teams that complete the endurance event will initially receive 100 points, and then be awarded additional points based on their energy consumption compared to the rest of the field [8]. The fuel economy improvement will be achieved via the engine tuning.

Snowmobile Design

Snowmobile Selection

The NIU Clean Snowmobile team members met and discussed many possible contenders that would allow for success in multiple categories; exhaust noise, exhaust emission, power to weight ratio, fuel efficiency and capability of running ethanol based fuels. The final decision was made to utilize the twin cylinder, two-stroke 599cc Polaris Indy. This snowmobile is one of many currently on the market that works well on both the trails as well as off trail riding. This model shares many parts with other current Polaris snowmobile models, which allows for a plethora of available parts.

The original engine used the Polaris "Clean Fire" system, as well as variable exhaust valves and a two injector fuel system. The factory settings are designed for either non ethanol or 10% ethanol blend. The motor we are running operates using the standard two cycle combustion cycle. In the case of modern snowmobiles, four-stroke engines are becoming more prominent. A four-stroke engine tends to last longer than a two-stroke and can be more reliable, however they are more expensive to make and maintain. However, we decided to keep the two-stroke engine that comes with our model snowmobile. Our intentions are to improve upon the current two-stroke engine and prove that it is a viable option for snowmobile manufacturers.

Braking System Modification

In the automotive market, anti-lock braking systems (ABS) are used to battle skidding and slipping while braking, although in the snowmobile market, where skidding can be a major problem, no such system has been made available until now. The Hayes Trail Trac 1.0 system acts as an ABS system would on a modern automobile. The system has its own speed sensor, separate from the factory speed sensor that monitors the speed of the track and not allowing it to completely lock up and cause a skid under hard braking conditions.

The braking system on the sled was replaced with a Hayes Trail Trac 1.0 system. The original system was a standard hydraulic disk brake system. The system was comprised of a standard single piston caliper controlled by a lever and master cylinder combination. The Trail Trac system contains the same components, but adds a hydraulic control unit, electronic control unit, and speed sensor. The system operates by controlling the brake force that is applied through the use of a hydraulic solenoid that is placed into the brake line. The system reads the track speed and prevents the brakes from locking and stopping the track. This not only allows for a more controlled stop, but also reduced stopping distance on most surfaces.

Big Wheel Kit

The NIU Clean Snowmobile team has made a modification to the drivetrain that includes adding a larger rear wheel to the skid. The larger rear wheel is designed to increase the fuel efficiency of the snowmobile by reducing the rolling resistance of the track, therefore losing less power from the engine due to friction.

To add this larger rear wheel to the stock snowmobile, some modifications had to be made. The first modification was to add a longer track in mainly to accommodate the larger rear wheel. Next and most importantly, was to relocate the rear axle in order to maintain tangency between the bottom of the skid and the rear wheel. The rear axle location also had to be moved backwards, away from the snowmobile, in order to accommodate for the longer track. In order to move the axle location, a bracket was designed to bolt into the factory axle location on the skid while creating a new location for the axle. This bracket can be seen in dark grey in Figure 1, seen below. The bracket was designed in such a way that the stock track tensioner remained fully functional in its original location.

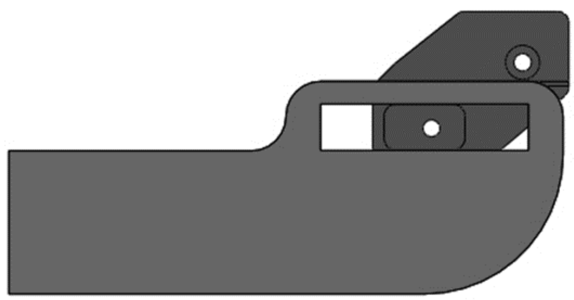

Figure 1: Mock Skid and Relocation Bracket

Since the stock axle location was moved up and away from the original axle location with the bracket, a twisting moment was created around the stock axle mounting location. The reaction forces in the system can be seen in Figure 2. It is pertinent to the structure of the snowmobile and the safety of the rider that this bracket does not impose any significant possibilities of failure during its use. The goal of the design was to prove that the factor of safety is greater than 2.0 for the bracket and the skid.

After the bracket was fabricated, the big wheel kit was installed on the 2015 Polaris Indy. In order to reduce possible damage to the wheels, the wheels were powder coated in a thick plastic paint. This ensured that the wheels would maintain their integrity, even with studs installed in the track. The big wheel kit, before the powder coating, can be seen in Figure 3.

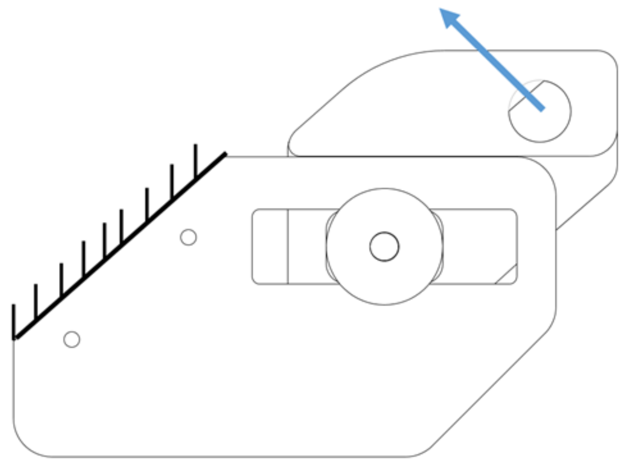

Figure 2: Reaction Force on Relocation Bracket

Figure 3: Big Wheel Kit on Polaris Indy

Exhaust Modification

The noise that is emitted by a snowmobile can be substantial. To help eliminate the most noise, the team decided to add an additional muffler into the exhaust system to help reduce the sound levels. The objective test is a SAE J1161 set by the National Park Service Winter Ruling. Each snowmobile cannot produce more than 67dBA. In order to achieve this, the team has added a Thrust Glasspack in line with the factory exhaust. A Glasspack is designed in order to have a straight through flow that is not restrictive to engine performance. The Glasspack is also filled with baffles and fiberglass packing helping to dampen the sound levels created by the snowmobile.

Real Time Ethanol Compensation

An important factor in the 2016 SAE Clean Snowmobile Competition is the fuel of choice. Since all teams will be given a fuel mixture that consists of 0% to 85% ethanol, it is pertinent that our snowmobile be ready for the entire range. This has been accomplished by replacing the stock ECU with the Vi-PEC ECU. The Vi-PEC allows for full modification of all engine parameters, including fuel injection, ignition timing, exhaust valve control, and many other parameters.

In order to utilize the Vi-PEC ECU, the team started by building a tune that would run the Polaris Indy on 93 octane gasoline. That tune was modified in order to maintain performance while also improving fuel economy and emissions. Once the first tune was built, a second tune was formulated to run the snowmobile on 75% ethanol. The addition of a GM flex fuel sensor allowed for monitoring of the ethanol content of the fuel. Given the natural resistance to detonation of ethanol fuels, this second tune was designed with a high air to fuel ratio (AFR) in order to improve fuel economy.

After the two tunes were completed, it was time to program the Vi-PEC ECU to perform real time fuel compensation for ethanol content. The initial gas tune was loaded onto the Vi-PEC ECU to be the stock tune. Inside of the Vi-PEC software, there is a fuel compensation option that can be turned on and controlled by the ethanol content signal coming from the GM flex fuel sensor. The second tune was then used to build the 4d fuel trim table. Since the second tune was built on 75% ethanol, the 4d fuel table values were calculated as projections of what would be needed for 100% ethanol.

Within the fuel correction settings of the Vi-PEC software, the ECU was programmed to linearly alter the fuel values between the gas tune and the 4d fuel table. The amount of fuel correction depends on the ethanol content determined by the flex fuel sensor. The exact same approach was taken for the ignition correction, which helps to advance timing depending on ethanol content.

Handling Improvements

The factory setup sled performed well in handling, while also offering the rider a great deal of control over the machine in most snow conditions. The areas that the team felt required improvement of the factory setup were that of the skis, carbides, brakes, and the track

The factory skis were replaced with a set of C&A Pro TRX skis. These skis offer improved steering control in loose snow conditions due to the shape. The skis also retained the factory weight. With the new skis Woody's Trailblazer 6inch carbides were also added. These carbides provide increased steering control on hard packed and icy conditions. The track was modified with the addition of Woody's Gold-Digger traction masters picks. These were added to provide increased traction in icy and hard packed snow conditions, when not only acceleration, but also turning and braking. The final area of handling improvements was due to the addition of the Hayes Trail Trac. The increase in the braking performance leads to a more controllable ride, especially in a situation with an inexperienced rider or an unexpected incident.

<u>Testing</u>

Brake System Testing

To test out this brake system we did a series of tests both pre-installation as well as post-installation of the Hayes Trail Trac 1.0. We tested the braking distance as well as the time of deceleration to a complete stop at each of our pre-determined speeds, see Appendix. After reviewing our data from both of the tests, it can be seen that stopping distance decreased, while deceleration time increased after installing the Hayes system. The biggest gain that was observed from this test was how the snowmobile handled subjectively during the tests. After the installation of the Hayes system, during braking, the handling was substantially increased. During the pre-installation test, the snowmobile was hard to handle and would go into a skidpushing it out sideways, during the post-installation test skidding was held to a minimum, the snowmobile was much easier to handle and did not try to push the track out from underneath the rider.

Big Wheel Kit Analysis and Results

For this experiment, it was necessary to mount the bracket in a manner similar to its attachment on the snowmobile. To do this, a model of the snowmobile's skid was machined. This also allowed for the mock skid to take the place of the full skid, which is over four feet in length. Since the main focus of this experiment was the rear of the skid, it was not necessary to have the entire skid. Creating the mock skid allowed for a much simpler experimental set up. The mock skid and bracket assembly is seen in figure __. This assembly not only simulates the make-up of the parts, but also allows the force to be applied in the proper direction by hanging dead weight from the new axle location, as shown in Figure 4.

Part of this experiment was to include FEA as well as strain analysis on this mock skid to ensure the entire skid-bracket assembly would withstand the maximum force. The possibility existed of increasing strain on the skid with the big wheel modification. Three separate strain gauge rosettes were used for the experiment; one on the bracket and two on the mock skid. Placement of the gages can be seen in Figure 5 and Figure 6.

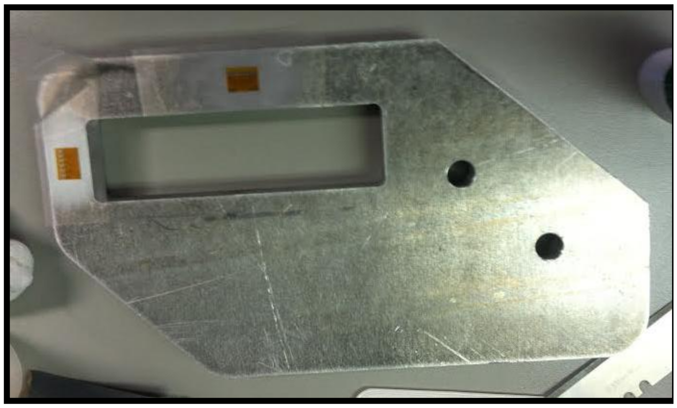

Figure 4: Experimental Setup for Relocation Bracket

Figure 5: Rosette Strain Gauges on Mock Skid

The locations of gage placement were chosen due to their high strain concentrations. It is of note that the highest strain concentrations in this experiment are located at areas such as radii and inside corners. However, these were not practical areas to adhere strain gages due to the interference of the mated parts as well as routing of the wire bundles.

Figure 6: Rosette Strain Gauge on Relocation Bracket

A finite element analysis (FEA) was completed in SolidWorks 2014 to establish a predicted outcome of the experiment. The mock skid and relocation bracket were modeled and assembled in the software. Since the scope of our experiment focused on the relocation bracket and the skid at the local point, it was decided to model only the section of the skid that is in close proximity to the original axle mounting location. The force was applied according to the reaction force shown in figure 5. The point strains for rosette gauge 1 and rosette gauge 2 at all simulated forces were recorded in order to have an accurate comparison to the experimental values.

It was determined that the design of the relocation bracket was safe and would withstand the maximum subjectable force of 500lb. Figure 11 shows a relatively uniform factor of safety calculated from the FEA, with a minimum factor of safety being 2.7. Also, the maximum stress was calculated at 15.5 ksi, which is well below the yield stress of the 6061 T6 aluminum, which is 42.0 ksi. This data gave confidence to the assumption that the assembly would not reach the yielding stress.

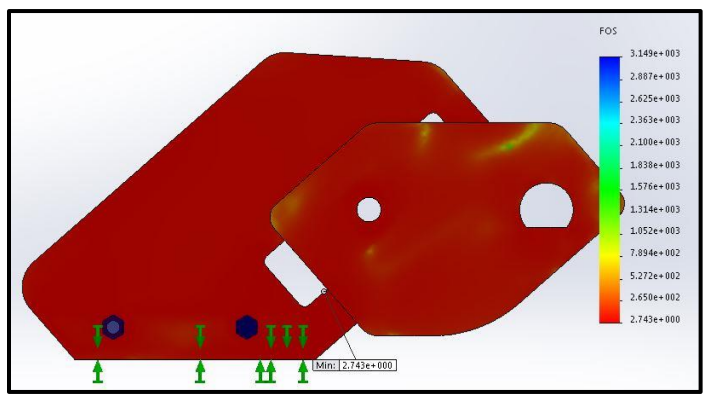

Figure 7: FEA Factor of Safety at 500 lb

After the physical experiment was conducted, the next step was to calculate the first and second principal strain present for rosette gauge 1 and 2.The principal strain was calculated by using the relationships of Mohr’s circle. Since the maximum experimental load was 300 lbf, and given that the strain relationship is linear to the force applied, a linear estimate was calculated for the principal strain for each rosette gauge. This linear estimate was then extrapolated to 500 lbf to produce an expected value of strain.

These linear estimates are overlaid on the calculated values of the first and second principal strain for rosette gauge 1 and 2 and presented in Figure 8 and Figure 9, respectively.

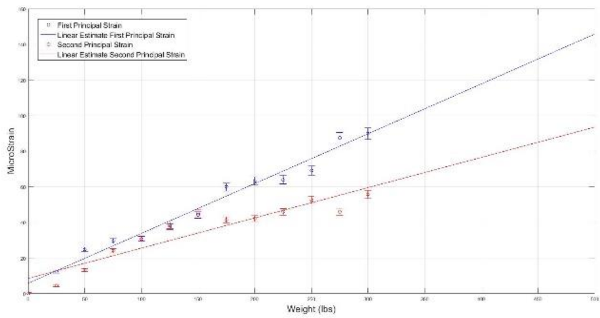

Figure 8: Rosette 1 Principal Strains with Linear Estimates

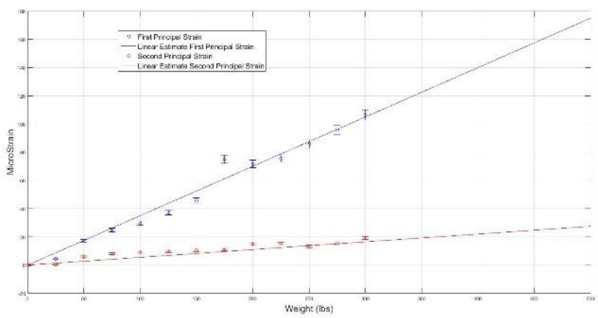

Figure 9: Rosette 2 Principal Strains with Linear Estimates

Through this experiment, it was confirmed that the relocation bracket was not dangerous and maintained the desired factor of safety. The experimentally calculated factor of safety was 2.5, while the FEA factor of safety was 2.7. The relocation bracket has been deemed acceptable and provides great value to the big wheel kit as a whole.

Noise Emission Testing and Analysis

Sound is formed from pulses of alternating high and low pressure waves [7]. These waves vibrate your eardrum for your brain to interpret. As it goes for most types of machinery, especially snowmobiles, sound is an unpleasant result that should be minimized if possible. This dilemma is one of many arguments for closing snowmobile trails to the public; whether it is preservationist concern about frightening animals, or land owners displeased with the noise pollution predominantly during night hours.

Total sound emissions from the snowmobile are currently measured using SAE J1161 specification [8]. The test calls for the snowmobile to run at 35 mph for 150 feet. The sound emitted from the tail pipe contributes to a majority of the total sound heard and the loudest of the overall sound emitted from the machine. This is caused by the pulsing and expansion of pressure waves from the combustion process.

Sound readings were taken in accordance to the SAE J1161 test. When measured at a distance of 50 feet perpendicular to the test track with the addition of the Glasspack the team was able to get a 9.2% reduction in the sound created by the machine over the factory set up.

Chemical Emissions Collection and Analysis

Chemical emissions were taken from the snowmobile via a Horiba MEXA 584L from a test pipe. The test pipe can be seen in figure 10.

Figure 10: Emissions Test Pipe

The probe was placed "seven diameters from the point in which the exhaust exits into the atmosphere is to prevent back pulses from reaching the sample probe". [8]

Emissions data was recorded for the stock snowmobile and can be seen in the appendix. The main area of focus was to compare the emissions with the Vi-PEC gasoline tune vs the Vi-PEC ethanol tune. The raw data can be found in the appendix, while a summary of results can be seen in figures 9 through 11.

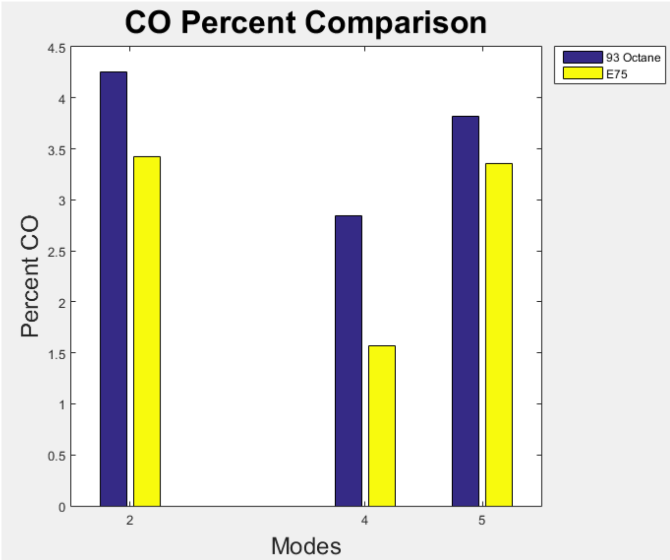

Figure 11: CO Emissions

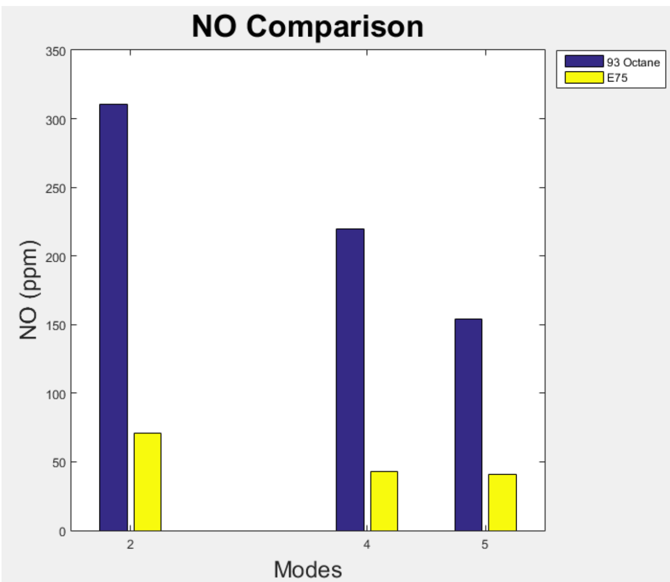

Figure 12: NO Emissions

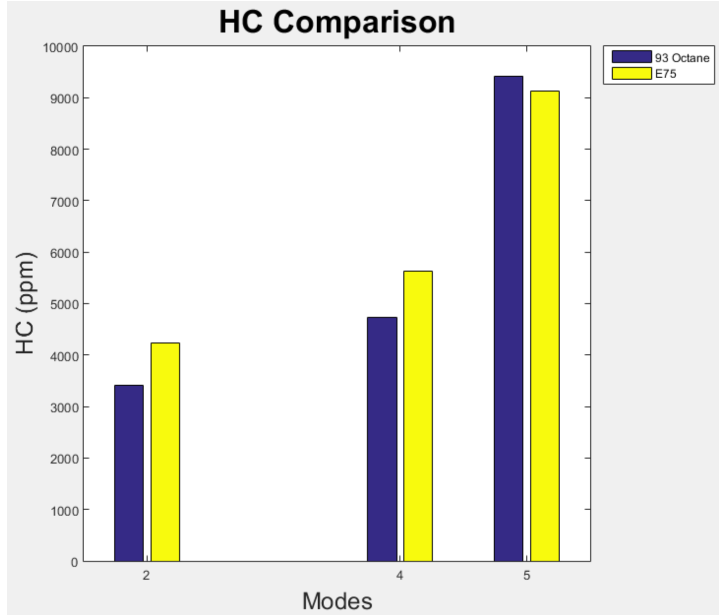

Figure 13: HC Emissions

Our data shows a reduction in NOx and CO. While a reduction in NOx and increase in HC is a natural reaction of ethanol based fuel, it can be shown that the relative reduction achieved by the NIU team is effective for the competition. While other emissions were recorded, the chemicals shown above were the most notable from our experiments.

The figures show that emissions were only recorded in modes 2, 4, and 5. This is the case due to difficulties encountered while operating our snowmobile on the dyno. Given the nature of a two stroke engine, combined with limitations in our equipment, it was not possible for our team to collect reliable data in modes 1 and 3. For that reason, it was excluded from our analysis. It is also of note that our emissions collection was not complete by the time of this paper being submitted. While we are improving our ethanol tune, we will also be taking more emissions data with the hopes of seeing a higher reduction in HC. Final results will be measured at the 2016 Clean Snowmobile Competition.

Consumer Appeal

All of the modifications on NIU's snowmobile can be applied to most current snowmobiles on the market. With rising prices in oil affecting prices at the pump, consumers are looking more toward fuel efficient engines, as well as practical alternative fuels, without having to sacrifice performance. Enthusiasts not only look for these qualities, but also for comfort, maneuverability, and a smooth-riding suspension.

Snowmobile design is constantly changing. Innovative ideas are continually being used to increase both fuel efficiency and performance. Snowmobile designers are constantly attempting to maximize all of these factors to make their snowmobile the most attractive to consumers, which is exactly what the Northern Illinois University Clean Snowmobile Team has done.

The Northern Illinois University Clean Snowmobile Team has designed a snowmobile that best fits the qualities that are highly sought-after when enthusiasts consider making a purchase. Speed and maneuverability were factors when designing the team sled; however these were not the only considerations… other factors were the continuing threats of prohibiting snowmobiling at popular snowmobile destinations, such as Yellowstone National Park, due to harmful environmental impacts related to the sport of snowmobiling. With these considerations the team was able to make a snowmobile that is both environmentally friendly, as well as high performance.

The sled has been designed to provide a high performance, efficient, and user-friendly alternative to the currently available market of snowmobiles. The consumer would be able to maintain the ride-ability that current sleds offer, while producing less harmful emissions and sound output. This is made possible by the use of pre-existing parts, and reduces the need for new parts to be designed or manufactured for a quick implementation.

Cost Effectiveness

The MSRP for the snowmobile designed by the Northern Illinois University team is $13,518.34. The modified 2014 Indy 600cc snowmobile designed costs $5,319.34 more than a 2016 factory model from Polaris. Many of the parts were sourced direct from the manufacturer or were obtained second hand. The cost for a manufacturer to build this snowmobile would be considerably lower than the cost listed here. Some of the most expensive added components were the Vi-PEC, the Hayes Traction Control Brake System, and the Camoplast track. The Hayes system dramatically increased the control of the snowmobile during braking. The VI-PEC was a necessary change because it was the only ECU that fit the model snowmobile and preserved the ability to drive the snowmobile in reverse. And the 128 inch Camoplast track was bought to accommodate for the custom big wheel kit that was designed for the snowmobile.

All of the stated modifications to the snowmobile are reasonably priced and any consumer can install them at home with relative ease. The modifications made by the NIU team also improved the fuel economy, which will save the consumer money at the pump. As a result, the final price of the NIU's clean snowmobile is a reasonable price for the overall quality of the snowmobile and the benefits it presents to its riders.

SUMMARY/CONCLUSIONS

The Society of Automotive Engineers (SAE) Clean Snowmobile Team at Northern Illinois University re-engineered a snowmobile for better noise and exhaust emissions. Over the year, prior to the competition, the team has designed, tested, and modified a snowmobile to the best of their capabilities-with the resources at hand. It is a cost-efficient snowmobile that has costumer appeal, rider safety, and user practicality.

The average consumer in today's economy desires fuel efficiency and lower emissions in their motor driven vehicles, this machine is no exception. Through fuel delivery modification, we have presented a snowmobile that can be operated on a clean and renewable fuel with substantially lower chemical emissions in comparison to those snowmobiles on the trails today. The Hayes Trail Trac 1.0 braking system improves the rider safety of the snowmobile, as well as the sport. This system emulates that of the ABS style brakes that would be found on any modern cars. A strong case is presented for making this system a stock feature on all snowmobiles.

We leave you with this consideration: Recreation Roundtable conducted a recent study on people who spent time outdoors. The results showed that these people lead "happier, healthier, and more productive lives [4]." They also were better citizens and neighbors in their community. It is our hope that through our work and the work of others involved in the SAE Clean Snowmobile Competition, the sport of snowmobiling will have a bright and future. With the current global environment, a clean future is a bright future; hopefully it can be our future.

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APPENDIX

Pre-Install Test

Stop Distance (feet)	Run 1	Run 2	Run 3
10 MPH	9.7	8.7	10
30 MPH	51	55	58.5
45 MPH	97	106	127.5
50 MPH	135	135	

Deceleration Time (Sec)	Run 1	Run 2	Run 3
10 MPH	1.5	1.2	1
30 MPH	2.8	1.8	2.8
45 MPH	3.6	3.6	3.2
50 MPH	4.2	4.2	

Post-Install Test

Stop Distance (feet)	Run 1	Run 2	Run 3
10 MPH	8.2	7.1	8.8
30 MPH	46.6	43.4	36.5
45 MPH	92	96	97
50 MPH	126.5	117	

Deceleration Time (	Run 1	Run 2	Run 3
10 MPH	1.3	1.2	1.6
30 MPH	2.9	3.3	3.5
45 MPH	3.7	4.2	4.5
50 MPH	4.5	4.8	

Pre-Install Test with studs

Stop Distance (feet)	Run 1	Run 2	Run 3
6 MPH	4.6	4.3	3.3
19 MPH	18.3	19.3	19
28 MPH	40	44.6	48.75
45 MPH	80		

Deceleration Time (Sec)	Run 1	Run 2	Run 3
6 MPH	0.7	0.6	1.5
19 MPH	1.4	1.4	1.6
28 MPH	2	2.3	2.4
45 MPH	3.2		

Post-Install Test with studs

Stop Distance (feet)	Run 1	Run 2	Run 3
6 MPH	2	2.5	2
19 MPH	21	20	19
28 MPH	49.75	46.6	36
45 MPH	84.5		

Deceleration Time (	Run 1	Run 2	Run 3
6 MPH	0.4	0.4	0.5
19 MPH	1.5	1.4	1.6
28 MPH	2.6	2.4	2
45 MPH	4		

Hayes Trial Track Testing

Target		Date	Time	RPM	Torque	HC(ppm)	CO(%)	CO2(%)	O2(%)	NO(ppm)
Torque		2/8/2016								
97.8	Mode	2/8/2016								
RPM		2/8/2016								
7500		2/8/2016								
Torque		2/8/2016		6400	52	6296	2.79	8.54	6.83	148
49.878	Mode	2/8/2016				7484	5.42	7.54	5.96	59
RPM		2/8/2016		6400	50	3436	3.82	8.26	6.3	37
6375		2/8/2016		6400	50	3688	1.66	9.96	5.86	40
Torque		2/8/2016								
32.274	Mode	2/8/2016								
RPM		2/8/2016								
5625		2/8/2016								
Torque		2/8/2016		4800	19	7324	0.562	8.64	9.07	39
18.582	Mode	2/8/2016		4700	19	6460	2.72	8.13	7.73	39
RPM		2/8/2016		4600	18.5	6932	2.47	8.44	7.4	45
4875		2/8/2016		4700	18	6700	0.52	8.41	9.4	50
Torque		2/8/2016				8688	3.14	4.5	12.2	34
0	Mode	2/8/2016				9544	3.5	4.42	12.21	40
RPM		2/8/2016				9176	3.04	4.24	12.51	41
IDLE		2/8/2016				9100	3.75	3.88	12.48	49

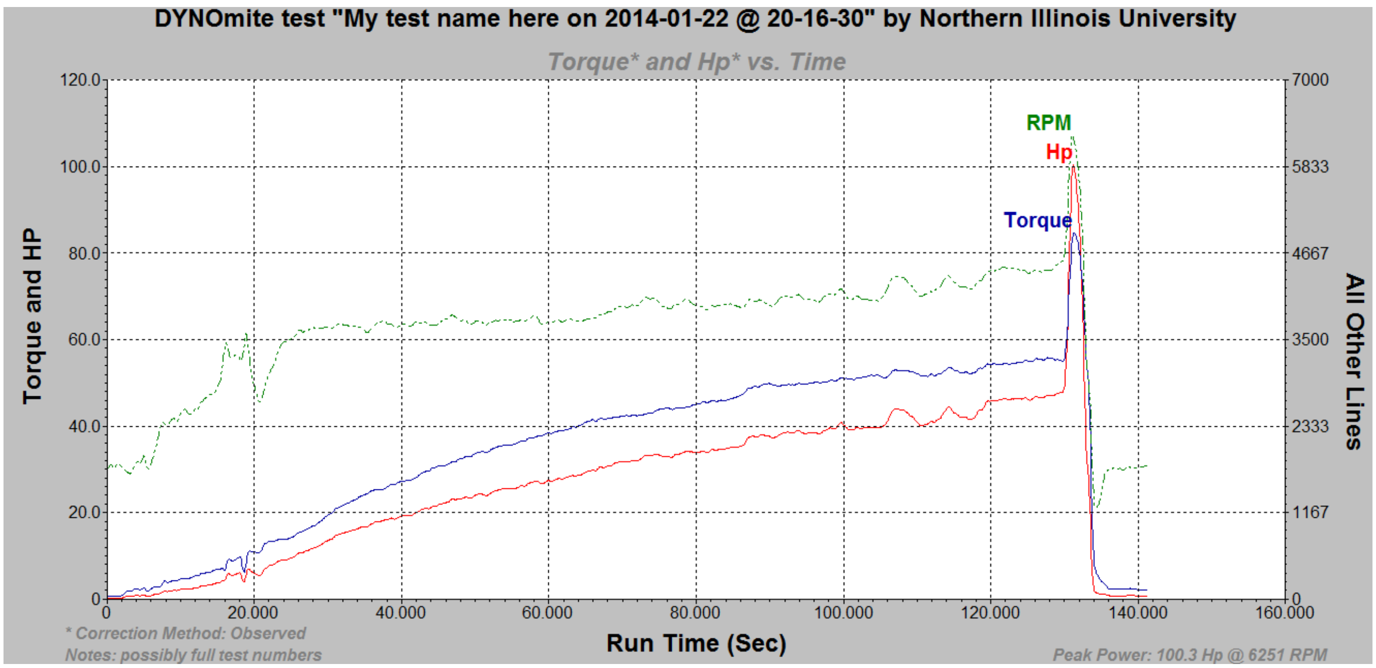
E75 Data

Target		Date	Time	RPM	Torque	HC(ppm)	CO(%)	CO2(%)	O2(%)	NO(ppm)
Torque		2/8/2016								
97.8	Mode	2/8/2016								
RPM		2/8/2016								
7500		2/8/2016								
Torque		2/8/2016	6:51	6200	48.5	3264	4.08	7.44	6.95	377
49.878	Mode	2/8/2016	6:56	6200	49.6	3232	4.83	6.98	6.89	247
RPM		2/8/2016	7:25	6200	48.8	3592	4.63	7.24	6.62	295
6375		2/8/2016	7:38	5827	46.5	3548	3.46	7.48	7.35	323
Torque		2/8/2016								
32.274	Mode	2/8/2016								
RPM		2/8/2016								
5625		2/8/2016								
Torque		2/8/2016	6:09	4700	20	5330	1.66	8.04	8.36	62
18.582	Mode	2/8/2016	6:15	4700	18.7	3830	2.28	8.16	7.5	60
RPM		2/8/2016	6:26	4400	17.9	3996	2.62	7.8	7.46	24
4875		2/8/2016	6:43	4700	18.5	5790	4.79	7.7	7.7	48
Torque		2/8/2016		2000	0	9280	3.79	3.7	12.05	50
0	Mode	2/8/2016	7:17	2300	0	9560	4.01	3.72	11.77	53
RPM		2/8/2016	7:41	2200	0	9410	4.15	4.4	10.64	55
IDLE		2/8/2016	7:46	2500	0	9450	3.33	4.64	11.19	58

93 Octane Data

	HC (PPM)			CO (%)			CO2 (%)			O2 (%)			NO (PPM)		
	93 OCT	E75	% Reduction	93 OCT	E75	% Reduction	93 OCT	E75	% Reduction	93 OCT	E75	% Reduction	93 OCT	E75	% Reduction
Mode 2	3409	4226	-19%	4.25	3.42	24%	7.285	8.575	-15%	6.9525	6.2375	11%	310.5	71	337%
Mode 4	4736.5	5625	-16%	2.8375	1.568	45%	7.925	8.405	-6%	7.755	8.4	-8%	220	43.25	409%
Mode 5	9425	9127	3%	3.82	3.3575	12%	4.115	4.26	-3%	11.41	12.35	-8%	154	41	276%

Comparison of 93 Octane vs. E75



Dyno Test for max power