Re-Engineering a 2011 Polaris Rush Two Stroke for the Clean Snowmobile Challenge 2014

Author, co-author (Do NOT enter this information. It will be pulled from participant tab in MyTechZone)

Affiliation (Do NOT enter this information. It will be pulled from participant tab in MyTechZone)

ABSTRACT

Northern Illinois University's Clean Snowmobile team will compete with a re-engineered 2011 Polaris Rush 600 in the 2014 Clean Snowmobile Challenge. The snowmobile will retain its factory equipped two stroke engine. The team has met the competition objectives which are to maintain or increase the snowmobile's performance while improving its exhaust noise and emissions. The stock Polaris ECU was supplemented with an add-on fuel controller to allow for the Isobutanol conversion. The motor was also modified to aid in the tuning procedure and to simplify the fuel system workings. These modifications were done with user friendliness, cost effectiveness, and clean emissions in mind. The snowmobile was setup to utilize already available consumer parts. The snowmobile was found to be a viable option for recreational riders and performance oriented riders as well.

INTRODUCTION

Northern Illinois' clean snowmobile team members have been a part of the snowmobiling community for the vast majority of their lives. 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. The combustion of fossil fuels by snowmobile engines raises environmental concerns in terms of air and noise pollution. 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 creates. This negative impact on the environment has created new objectives for college students [1].

The team began with a 2011 Polaris rush 600 that met factory specifications. The first goal the team established was to create a system to make the snowmobile perform on the new Isobutanol fuel blend. The sled has minor modifications to simplify the overall design. The team has had difficulties in the past with overly modified machines that hindered ease of use, adjustability and reliability.

This year the team's goal was to successfully compete in the competition while also improving upon the factory snowmobile. Building off of last year's downfalls the team has focused on sustainability, endurance, efficiency and reliability. The team emphasized simplicity in the design. The team achieved this by only focusing on areas of the snowmobile that would need to be changed to function to allow the snowmobile to participate in the competition. The team also wants to prove that a traditional two stroke motor is a viable option for this competition, and is looking to help improve the current two stroke offerings of the market.

Team Objectives

Reduce Exhaust Emissions

The Northern Illinois University (NIU) team's primary objective is to lower the exhaust emissions. A five mode test will be conducted to verify that each snowmobile complies with the 2013 EPA standards. Table 1 clearly identifies each mode and corresponding categories.

Table 1: 5- 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].

$$E = \left[1 - \frac{(HC + NOx) - 10}{150}\right] \times 100 + \left[1 - \left(\frac{CO}{400}\right)\right] \times 100 \geq 100 \quad [1]$$

The quantities of each are use in the formula [1] to calculate the team's emission number, where the emission number (E) must exceed 100. The emission number for each team will be used to calculate their final score

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 Isobutanol blended gasoline. This blend ranges from a 16% to 32% mixture. This change in fuel requires a change in fuel mapping, which allows for a change in the fuel economy of the sled. This year's major change was to add onto the factory ECU to allow adjustments to be made to the timing and fuel maps as well.

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].

Performance Characteristics

On top of producing a snowmobile that is better for the environment, teams are challenged with the objective of retaining or improving upon the performance characteristics. These characteristics include power, control, and handling. There are two events that will help expose the differences in performance between each team's snowmobile. There are specific events that test the acceleration, control, and handling of the snowmobile. The acceleration event will test each snowmobile from a standing stop to the maximum speed it can reach in 500 feet. The teams will take the best time of two runs, and the elapsed time must be no more than 12 seconds [8]. Also, all snowmobiles will compete in a timed control and handling event. This event will assess the maneuverability of each snowmobile by having them complete two individual laps on a slalom style course. The best lap time will be recorded.

Furthermore, there are other objectives including cost effectiveness, cold start, rider comfort, design paper, and design presentation that each team will be judged on. Each objective is equally important to the design of a snowmobile, especially the conversion to an Isobutanol platform for the 2014 Clean Snowmobile Challenge.

Conversion to Isobutanol

The Clean Snowmobile Challenge brings different and new engineering objective each year. This year's challenge is to convert a snowmobile engine to run on an Isobutanol.

Background Information on Isobutanol

Isobutanol is one of the newest chemicals in the 2nd generation of biofuels. This new chemical's relatively high energy density, 98% of gasoline, [5] is a very promising since ethanol only had about 67% the energy density of gasoline. As of right now the production of Isobutanol is growing rapidly as the tests are proving that it possibly a better solution then ethanol. A problem for the future of ethanol is engine failure which research is proving. The reasoning behind this is "Ethanol adds oxygen, making engines run hotter, so if they increase the amounts to 15% in the gasoline that could lead to mechanical failures." [3] Because of this the 2nd Generation of biofuels needed to happen.

The chemical composition of gasoline is C8H18. This means for the chemical reaction you need to add a lot of oxygen. The chemical composition of Isobutanol is C4H10O. This means when Isobutanol is used in a chemical reaction less hydrocarbons are produced. This makes the fuel additive more environmentally friendly. When burned, Isobutanol emits tailpipe emissions which contain far less climate altering greenhouse gases than unleaded gas.

Isobutanol is produced from sugar from farm waste which includes corn, wheat, wood, etc. This is a step up from ethanol because it could only be produced from corn. Then a biocatalyst is used, followed by a separator. This produces Isobutanol and/or renewable hydrocarbons. [3]

Isobutanol Conversion in Snowmobiles

Transitioning from running a snowmobile off of gasoline to making it run on a mixture of Isobutanol and gasoline is not an overly difficult task. Isobutanol, being a drop in substitute for other fuel additives [6], can be easily introduced into existing systems without extensive modification. Isobutanol has 98% the energy density of gasoline [5], so making up for the difference while tuning only takes minor adjustments of the fuel table to compensate. Also, Isobutanol can be used in both 2 and 4 stroke snowmobile motor applications due to the fact that it will not only mix with gasoline but also the gasoline and oil mixture used to run 2 stroke motors.

Snowmobile Design

Snowmobile Selection

The NIU Clean Snowmobile team members met and discussed possible candidates that would allow for success in multiple categories; exhaust noise, exhaust emission, power to weight ratio, fuel efficiency and capability of running Isobutanol based fuels. The final decision was made to utilize the twin cylinder, two-stroke 599cc Polaris Rush. 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 suspension design is unique to the Rush and switchback chassis. The front suspension is a traditional a-arm style while the rear suspension is model specific.

The 2011 Polaris Rush 600cc is one of Polaris's snowmobiles that utilizes the "Pro-Ride" suspension system. This chassis offers increased rigidity for precise, intuitive handling.

Figure 1: Polaris Pro-Ride Rush Chassis

The increase in the rigidity of the chassis allows for a smoother and tighter riding snowmobile. The Rush was factory equipped with a traditional two stroke in-line twin cylinder engine. This engine runs on 89 Octane fuel with 10% ethanol or 91 Octane fuel.

This engine uses the Polaris "Clean Fire" system. The engine has variable exhaust valves, and a four injector fuel system. The four injector system combines both cylinder direct injectors with crankcase injectors as well. The crankcase injectors are used when the motor is at or below 10% throttle. These injectors allowed for slight cooling of the engine as well as providing smooth response at the lower end. The motor 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. With less moving parts, and parts overall, a two-stroke engine is smaller, lighter, cheaper to manufacture, and is easier to repair than the typical four-stroke engine [2].

The two cycle engine operates with only two stages in its combustion cycle. There is a power stroke and combustion stroke. The motor's air is drawn into the crankcase, instead of directly into the cylinders. The air charge is then drawn into the cylinder through the intake port. The air fuel charge is then compressed during the compression stroke. It is during this stroke that the air/fuel mixture is ignited and enters the power stroke. The burnt exhaust gas mixture is then expelled out of the engine when the exhaust port is opened. There is a portion of the exhaust gases scavenged into the cylinder for the next combustion stroke. The engine also injects oil into the crankcase to lubricate the surfaces. This oil is in turn burnt in the air fuel mixture. This mixture of the oil, air, and fuel is what results in the currently unclean nature or "smokey" nature that has plagued two stroke motors. The two stroke motor relies on ports in the cylinder walls instead of moving valves to control the flow of the air, fuel, and exhaust. This leads to a lower number moving parts; some two strokes having as little as three moving parts internally.

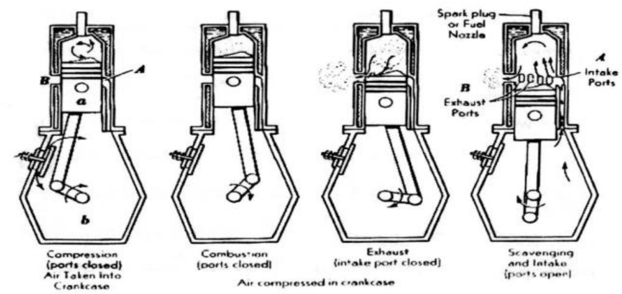

Figure 2: Two Cycle Engine

Engine and ECU Modifications

New rules from the CSC 2012 forced teams to run a more advanced Engine Control Unit (ECU). In previous years the ethanol fuel at the CSC competition was winter blend E85, or E70, throughout the entire competition. Since the 2012 CSC competition teams did not know the ethanol content of the fuel, only that it would range anywhere from E10 to E39 winter blend at any point in the competition. This requirement is a realistic expectation for any snowmobile that would be labeled "flex fuel," but it does add considerable requirements to the engine. The 2014 CSC rules are requiring the engine to run on an Isobutanol blend. This poses a new challenge to the teams.

The factory engine used a four injector setup that would run on the crankcase injectors while below 10% throttle. The remaining portion of the throttle transfers to the cylinder injectors. The four injector system allows for the motor to burn cleaner at lower end speeds, while at higher speeds, the crankcase injectors are not utilized, reducing emissions because less oil is being injected into the cylinder.

The factory settings are designed for either non ethanol or 10% ethanol blend. The factory ECU settings were modified with the use of a Dynojet Research Inc. Power Commander V piggyback system. This module allows for modifications to the factory ECU. An auto-tune module was also added to allow the snowmobile to adjust the fuel map based on the air fuel ratio read from the wideband oxygen sensor. The advantage of this additional system is that it adjusts the mapping based on either performance or efficiency settings. The sensor was placed in the expansion chamber of the exhaust. The location was chosen to lower the possibility of unburnt oil contaminating the sensor. The location is also far enough away from the engine that the scavenging effect would not affect the readings.

The ECU also allows for a user selectable map switch to be installed. The advantage of this switch is to allow the rider to switch between two different predetermined maps. The maps would be a performance setting, as well as a fuel efficiency setting. This switch allows the sled to be tailored to allow both high fuel mileage for trail riding and the high performance setting for off trail riding.

Braking System Modification

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.

Testing

Dynamometer Runs

In order to accommodate for the requirements of CSC 2014, the team placed the engine under a variable load to simulate different riding conditions; as well as to check any performance changes after modifications were implemented. The test was performed with a Land and Sea nine inch toroidal flow water break dynamometer. The dynamometer allows simulation of a real world environment by placing variable loads on the engine while simultaneously monitoring the internal and external diagnostics of the snowmobile. The team is able to monitor rpm, horsepower, torque, exhaust gas temp, air intake flow, air/fuel ratio as well as all of the factory parameters the sled measured.

Exhaust Emission Testing and Analysis

Emissions of a snowmobile are quite high in reference to a typical automobile driven on the road. Due to this, emissions of snowmobiles have been under a lot of scrutiny. For cleaner air and to better our environment, snowmobile emissions have been regulated by the government in recent years. The team focused on reducing the exhaust emissions of the two stroke engine by running synthetic blend oil, switching the fuel over to the iso-gasoline blend, and by refining the tuning to reduce overly rich sections in the original fuel mapping. If the engine can be kept in an ideal stoichiometric air fuel ratio, the engine will be producing its highest power with the least emissions. The tuning of the engine was designed to eliminate areas where the engine would have excessive amounts of fuel being used to reduce the amount of unburnt fuel in the exhaust stream, as well as increase the engines fuel economy.

The NIU Clean Snowmobile Team has access to a Nova five gas exhaust analyzer. During the dynamometer runs, the team was able to measure the exhaust gas content of the snowmobile. The exhaust gas readings were taken while the motor was placed under the EPA Five Mode test. The emissions were collected every 15 seconds, which was the fastest time the computer software was capable of logging.

Table 2. Emissions collected during EPA Five Mode test, values averaged over the entire collection period.

	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
MODE 1	16.62	1.95	1.97	4469	0	0.5
MODE 2	18.38	1.07	1.28	1783	0	2.5
MODE 3	20.33	0.27	0.45	795	0	0
MODE 4	16.07	0.53	3.4	2732	0	5
MODE 5	19.27	0.83	0.72	2133	0	0

The engine was tested running on 93 octane ethanol free fuel. Due to an unforeseen issue that arose with the ECU and dyno, the sled was not used on the dyno or emissions tester while running on the Isobutanol blended fuel. The values that were collected from the sled were taken from a test port placed in an exhaust pipe extension, see appendix. The exhaust extension was designed to meet the rules for the emissions testing equipment.

Figure 3: Emissions test pipe and probe

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]

Noise Emission Testing and Analysis

Sound is formed from pulses of alternating high and low pressure waves [7]. These waves will 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. This dilemma is one of many arguments for closing snowmobile trails to the public; whether it is environmentalist concern about frightening animals, or land owners displeased with the noise pollution primarily during night hours.

Total sound emission from the snowmobile is currently measured using SAE J192 specification [8]. The test calls for the snowmobile to accelerate for 150 feet with the measurement taken at 50 feet perpendicular to the lane. 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 J192 test. The measured decibel reading was found to be a max of 76.9 dB. The conditions for the test were such that there was no wind, temperature of 19 degree Fahrenheit, and pressure of 30.23 inHg. The sled also produced a reading of 81 dB when passing by the microphone 50ft away at full throttle.

Brake System Testing

In the automotive market, ABS systems are used to battle skidding while braking while in the snowmobile market, where skidding can be a major problem, no such a 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.

To test out this brake system we did a series of tests both pre-installation and 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 skid pushing it out sideways, while 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.

Consumer Appeal

All of the modifications on NIU’s snowmobile can be done by the average snowmobiler at home with basic tools using parts available to all consumers. 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 banning snowmobiling of 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 was 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. The use of pre-existing parts reduces the need for new parts to be designed or manufactured.

Safety of the Rider

When designing the sled, the safety of the operator was another important consideration of the team. We utilized the factory shielding of moving components because we did not modify stock drive line. More aggressive Woody's carbides were implemented under both skis in order to improve handling and responsiveness of the snowmobile. Woody's picks were implemented on the track to help fight skidding and sliding in low traction conditions. The Hayes Trail Trac 1.0 system was installed to minimize skidding while braking and decrease braking distance.

Cost Effectiveness

The MSRP for NIU clean snowmobile is $12,957. The modified 2011 600 Polaris Rush sled has a couple benefits over the compared 2014 600 Rush Pro R sled. A few of the most expensive modification include the Hayes Trail Trac, The Dynojet Power Commander, and the Gold digger Traction Master. The Hayes Trail Trac greatly increased the control of the snowmobile during braking. The DynoJet Power Commander V is an addition to the ECU will make it possible for the modified sled to be properly turned. Finally the Gold Digger Traction Master studs, these studs added to the track will increases the traction during acceleration and increases control during braking. All off the stated modifications to the sled are reasonably priced and any consumer can install them at home with relative ease. Therefore, 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 rider.

SUMMARY/CONCLUSIONS

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. As snowmobiling increasingly becomes more popular in future years, the effort for improved, dependable, and environmentally friendly vehicles will take manufacturers to a new level. SAE takes an additional step by challenging engineering students to perform many of these efforts.

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

One of the more important modifications made to the machine was the integration of the Dynojet Power Commander. This device allows for the easy adjustment of stock fuel mapping in conjunction with the stock ECU. This system is also relatively easy to install, so easy that the average snowmobile enthusiast can make changes to their snowmobile at home. Another strong improvement to this machine is the installation of the Hayes Trail Trac 1.0 braking system. This system emulates that of the ABS style brakes that would be found on any modern car. This braking system allows for greater safety and control of the machine during braking and makes the rider feel safer when they must brake at high speeds or in poor traction situations. This braking system restricts the brakes and track from locking up and prevents sliding during the braking process.

This snowmobile has the ability to run on alternative fuel blends. The changes made result in fewer pollutants than a standard two stroke engine. Also, by making the engine more efficient, and by important modifications like high performance brakes, fuel economy is boosted beyond what most stock sleds are capable of. The average consumer in today's economy desires fuel efficiency in their motor driven vehicles, and this machine is no exception. The modifications made to this machine will allow for a higher fuel economy along with lower emissions, fulfilling both of those desires. The biggest improvement to the machine is the decreased pollution from the two stroke engine. The improvements will allow for one to ride in even some of the most emission restrictive areas around the United States, such as Yellowstone National Park.

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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

Average emissions Collectd for Each Mode

	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
MODE 1	16.62	1.95	1.97	4469	0	0.5
MODE 2	18.38	1.07	1.28	1783	0	2.5
MODE 3	20.33	0.27	0.45	795	0	0
MODE 4	16.07	0.53	3.4	2732	0	5
MODE 5	19.27	0.83	0.72	2133	0	0

MODE1	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	15.7	2.3	2.4	5054	0	1
	16	2.2	2.2	4930	0	1
	16.4	2	2	4614	0	1
	16.9	1.9	1.9	4352	0	0
	17.2	1.7	1.7	4054	0	0
	17.5	1.6	1.6	3814	0	0
AVG	16.61667	1.95	1.966667	4469.667	0	0.5

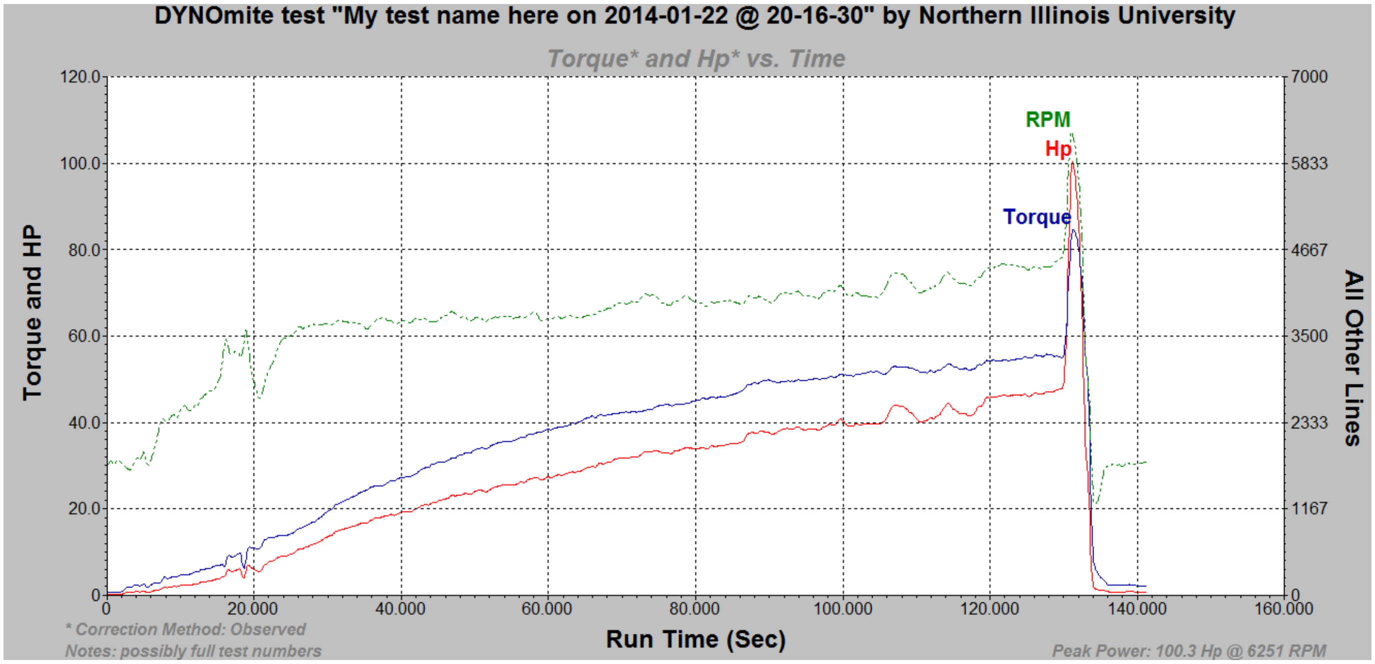
MODE2	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	17.4	1.2	1.7	1799	0	4
	18	1.2	1.4	1844	0	4
	18.4	1.1	1.3	1848	0	3
	18.6	1	1.2	1800	0	2
	18.9	1	1.1	1734	0	1
	19	0.9	1	1677	0	1
AVG	18.38333	1.066667	1.283333	1783.667	0	2.5

MODE3	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	20.3	0.3	0.4	816	0	0
	20.4	0.3	0.4	803	0	0
	20.4	0.3	0.4	793	0	0
	20.4	0.3	0.4	791	0	0
	20.3	0.2	0.5	791	0	0
	20.2	0.2	0.6	781	0	0
AVG	20.33333	0.266667	0.45	795.8333	0	0

MODE4	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	16.1	1.4	2.7	3204	0	3
	16	0.7	3.4	2827	0	3
	16	0.4	3.5	2701	0	3
	16.1	0.3	3.6	2617	0	5
	16.1	0.2	3.6	2551	0	7
	16.1	0.2	3.6	2495	0	9
AVG	16.06667	0.533333	3.4	2732.5	0	5

MODE5	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	19.1	0.9	2.1.04	2300	0	0
	19.1	0.8	0.9	2164	0	0
	19.2	0.9	0.9	2045	0	0
	19.4	0.8	0.8	2012	0	0
	19.3	0.9	0.8	2024	0	0
	19.5	0.7	0.9	2254	0	0
AVG	19.26667	0.833333	0.716667	2133.167	0	0

Emission Data



Dyno Test for max power

Average emissions Collectd for Each Mode								MODE3	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
									20.3	0.3	0.4	816	0	0
	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2			20.4	0.3	0.4	803	0	0
MODE 1	16.62	1.95	1.97	4469	0	0.5			20.4	0.3	0.4	793	0	0
MODE 2	18.38	1.07	1.28	1783	0	2.5			20.4	0.3	0.4	791	0	0
MODE 3	20.33	0.27	0.45	795	0	0			20.3	0.2	0.5	791	0	0
MODE 4	16.07	0.53	3.4	2732	0	5			20.2	0.2	0.6	781	0	0
MODE 5	19.27	0.83	0.72	2133	0	0		AVG	20.33333	0.266667	0.45	795.8333	0	0
MODE1	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2		MODE4	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	15.7	2.3	2.4	5054	0	1			16.1	1.4	2.7	3204	0	3
	16	2.2	2.2	4930	0	1			16	0.7	3.4	2827	0	3
	16.4	2	2	4614	0	1			16	0.4	3.5	2701	0	3
	16.9	1.9	1.9	4352	0	0			16.1	0.3	3.6	2617	0	5
	17.2	1.7	1.7	4054	0	0			16.1	0.2	3.6	2551	0	7
	17.5	1.6	1.6	3814	0	0			16.1	0.2	3.6	2495	0	9
AVG	16.61667	1.95	1.966667	4469.667	0	0.5		AVG	16.06667	0.533333	3.4	2732.5	0	5
MODE2	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2								
	17.4	1.2	1.7	1799	0	4		MODE5	%O2	%CO	%CO2	PPM HC's	PPM NO	PPM NO2
	18	1.2	1.4	1844	0	4			19.1	0.9	2.1.04	2300	0	0
	18.4	1.1	1.3	1848	0	3			19.1	0.8	0.9	2164	0	0
	18.6	1	1.2	1800	0	2			19.2	0.9	0.9	2045	0	0
	18.9	1	1.1	1734	0	1			19.4	0.8	0.8	2012	0	0
	19	0.9	1	1677	0	1			19.3	0.9	0.8	2024	0	0
AVG	18.38333	1.066667	1.283333	1783.667	0	2.5			19.5	0.7	0.9	2254	0	0
								AVG	19.26667	0.833333	0.716667	2133.167	0	0

Emissions Data