Modifications to a 2002 Polaris Pro-X 440 to Compete in the Clean Snowmobile Challenge 2007

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ABSTRACT

A 2002 Polaris Pro-X 440 was redesigned to compete in the 2007 Clean Snowmobile Challenge. The objectives were to engineer a quiet, clean, high performance snowmobile. Along with these important features the group also wanted to design a snowmobile that was rider, manufacturer, and environmentally friendly. While meeting these objectives, the performance characteristics that consumers have come to expect needed to be maintained or improved on the snowmobile. To achieve these objectives, the team replaced the Polaris carbureted two stroke engine with a Rotax semi-direct injected (SDI), two-stroke engine. A catalytic converter and secondary air injection pump were added into the exhaust system under the hood to reduce the emissions. The University of Wisconsin-Platteville (UW-P) team also added a modified Ski-Doo silencer to the exhaust system to reduce the noise associated with the exhaust process. The modifications on the snowmobile achieved UW-P's goals in a cost-effective manner, while maintaining reliability.

INTRODUCTION

The 2007 Clean Snowmobile Challenge is an engineering design competition for college and university student members of the Society of Automotive Engineers (SAE), organized and administered by the SAE, and the Keweenaw Research Center (KRC).

The challenge is to modify a production snowmobile to improve emissions, reduce noise, while maintaining or improving the performance characteristics of the snowmobile. The modified snowmobile competes in the Clean Snowmobile Challenge starting March 19, 2007 in Houghton, Michigan. The competition consists of events including cold start, fuel economy, acceleration, handling, rider comfort, emissions, noise, and design. These events are spread over a six-day period [1].

The University of Wisconsin-Platteville SAE Clean Snowmobile team's overall objectives for the competition are to modify a snowmobile that:

1) Meets noise and emission requirements
2) Maintains or exceeds stock performance characteristics
3) Compete for a top five finish at the Clean Snowmobile Challenge 2007

TEAM BACKGROUND

The Clean Snowmobile Team (Figure 1) is one of several student design and competition teams within the SAE student chapter at UW-P. The project is managed and directed by the students, with the assistance of an advisor and the Department of Mechanical Engineering. The team is funded through the Segregated University Fee Allocation Commission (SUFAC), team fundraising, and commercial sponsors.

Figure 1: 2007 Clean Snowmobile Team

DESIGN STRATEGY

The UW-P Clean Snowmobile Team's intent was to modify a snowmobile to provide a successful entry in the 2007 Clean Snowmobile Challenge. The team has set out to meet the competition requirements for sound and emissions as well as maintaining the qualities desired in a production snowmobile by today's consumer standards.

Design constraints and criteria relevant to the modifications made to the snowmobile are outlined in the report to follow. A complete set of the constraints and criteria are provided in the Clean Snowmobile Challenge competition rules [1].

DESIGN CONSTRAINTS [1]

- Modifications to the engine, including substitution of a different engine is allowed. Two-stroke, four-stroke, and rotary engines are allowed. Engine displacement is limited to 600 cc or less for two-stroke and rotary engines, 960 cc or less for four-stroke engines.

- Snowmobiles must be fueled with ethanol fuel blends. The choices are E10 (nominally a blend of 10% ethanol and 90% premium gasoline) or E85 (nominally 85% ethanol and 15% premium gasoline). Refer to ASTM D5798-99 Standard Specifications for Fuel Ethanol for Automotive Spark Ignition Engines. Class 3 will be used at the Challenge (70% Ethanol). Note that E85 winter blend usually is blended with 70% to 79% ethanol to improve starting and running in the cold weather. All references to E85 in the rules imply winter blend E85 Class 3.
- The snowmobile must be propelled with a variable ratio belt transmission.
- The modified snowmobile must also meet or exceed all applicable safety standards
- The snowmobile's track may be replaced with a different track. The track must be a commercially available, one piece, molded rubber snowmobile track and cannot be modified.
- Ski and front suspension may be modified. However the snowmobile must remain ski steered, have at least six inches of suspension travel
- The use of traction control devices such as ice grousers, or paddles is not allowed; however, studs are allowed.

The team's first major decision was the use of a two-stroke engine because of the existing consumer confidence and the performance qualities of this engine. This engine selection meets most of the design criteria and goals. Strategy then focused on increasing the efficiency and power of the engine. Careful consideration was given to assure that these modifications did not exceed limitations set for emissions, noise, reliability and safety.

DRIVELINE IMPROVEMENTS

A large factor in driveline efficiency with a variable ratio belt transmission is tuning the clutches to transmit maximum power to the track. The effect of clutch tuning can be seen in the horsepower graphs, Figure 3 and Figure 4. The ideally tuned clutch set up should follow a path similar to that shown in Figure 2. [6]

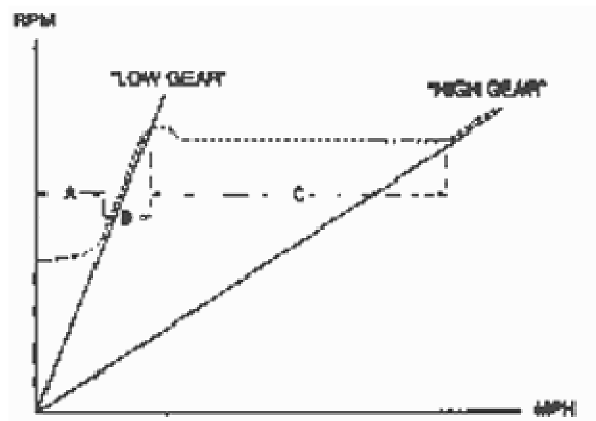

Figure 2: **Properly Tuned Clutches (MPH vs. RPM)**

The first thing that must be considered in clutch tuning is the engagement speed shown as segment A in Figure 2. The engagement speed should at the lowest speed possible without creating engine bog. If the engagement speed is set too high damage to drive components can occur and can be very difficult to control a slow takeoff driving the snowmobile. Segment B in Figure 2 is the low gear acceleration, and segment C is the up shifting acceleration. These two segments must be set properly in order to achieve the quickest acceleration.

The most important aspect of clutch tuning is controlling the engine speed so that it coincides with the rpm, at which the engine creates the highest horsepower. With a two-stroke engine, this maximum horsepower occurs over a very short range of rpms. In order for the engine to remain running in this range, the weights and springs on the primary clutch must be adjusted. Along with adjusting the primary clutch, the spring and cam angle on the secondary clutch must also be adjusted to keep the engine operating at its maximum power through the entire acceleration run. [6]

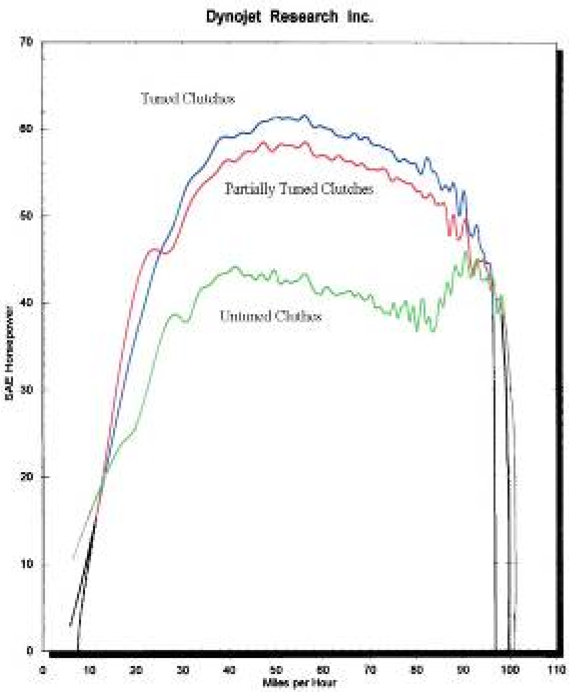

Figure 3: Track Horsepower

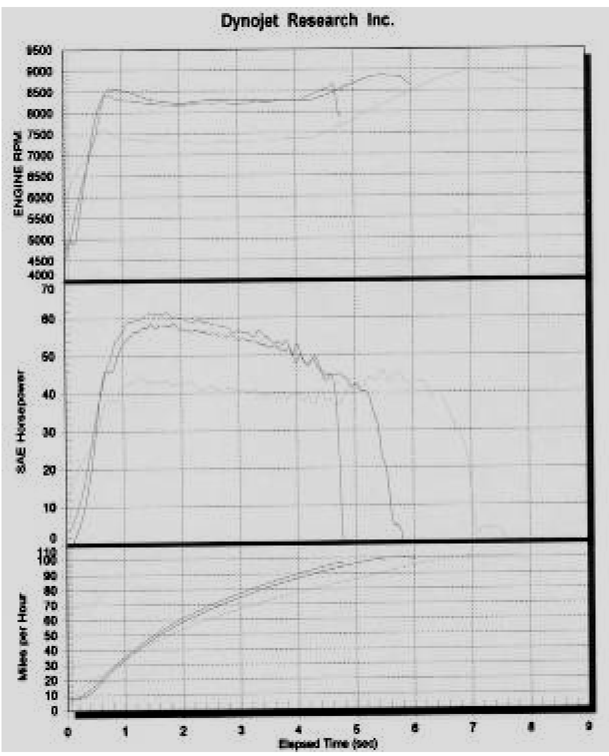

Figure 4: Dynamometer Results

The Polaris Pro-X suspension features the use of aftermarket slides. These Hiperfax slides utilize Teflon inserts that improve driveline performance by reducing friction between the rails of the skid frame and the track. As the snowmobile is driven, the Teflon coating is spread onto the track clips in order to create a Teflon-to-Teflon contact area. While most slides have a melting point near 300^{o}F, Hiperfax slides have a melting point close to 700^{o}F. By increasing the melting point of the slides, the chance of the slides approaching these temperatures under poor trail conditions is greatly reduced. If the slides approach their melting temperature they will increase the kinetic friction between them and the track, reducing driveline efficiency. Gains in fuel economy of three to four gallons per mile have been seen with the use of Hiperfax slides. These gains in fuel economy are due to the decreased friction in the track-slide interface. [7]

Hiperfax slides and properly tuned clutches have helped in achieving the goal of increasing driveline efficiency.

NOISE REDUCTION

With noise pollution issues being one of the main focuses of the competition, noise was a primary concern for this year's snowmobile. After a weak performance in the noise event last year, the noise reduction on the snowmobile was a primary concern. Several sources that contribute to increased noise levels from snowmobiles were investigated. The two major sources investigated were the engine, drive train, and exhaust. To reduce the total amount of noise emitted, each source of noise was individually evaluated and the best solution was determined for each case.

ENGINE NOISE REDUCTION

One of the significant sources of noise on a two-stroke snowmobile is the exhaust system. Exhaust noise is created from the pressure pulses exiting from the exhaust ports and resonating through the exhaust system. The pressure and flow rate of air through the exhaust system creates a large source of noise. Thus the exhaust system received a great deal of attention to reduce noise levels, which resulted in considerable modification to the stock exhaust system.

The entire exhaust system was modified to reduce the noise emissions from the exhaust. From the stock Rotax manifold, the exhaust goes through a custom expansion chamber and exits into the catalytic converter. After the catalytic converter, the exhaust system continues to a double core silencer. The silencer has a unique stinger design to reduce noise. The double core silencer is packed with long strand high density fibers to further muffle noise. The exhaust then exits the hood and under the gas tank to a secondary silencer. The secondary silencer was modified from a stock Rotax 600cc silencer. The Rotax 600cc silencer was packed with fiberglass around the center chamber as seen in Figure 5. The center chamber absorbs the higher frequency sound energy into mechanical vibration and heat [11]. From the secondary silencer, the exhaust exits into the tunnel near the rear of the snowmobile. By exiting the exhaust into the tunnel, noise was reduced by three to four decibels depending on the rpm of the engine.

Figure 5: Modified Rotax 600cc Silencer

Sound testing was done with various modifications and the results can be seen in Figure 6. These experimental tests were performed at a constant speed pass of 35 miles per hour with measurements taken at a distance of 50 ft.

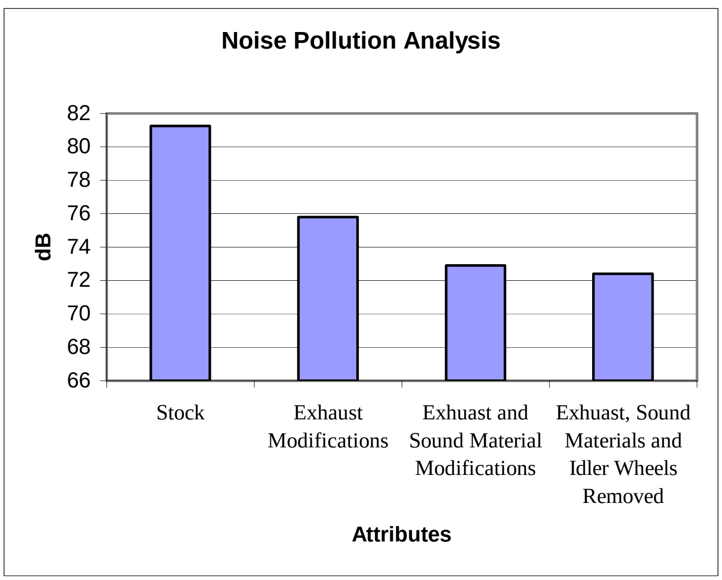

Figure 6: Noise Pollution Analysis

DRIVETRAIN NOISE REDUCTION

In the drive train, the main producers of noise are the chain case, track, idler wheels, and the continual variable transmission clutches. The chain case creates a high frequency noise due to unavoidable gears to chain mess and the chain contacting the roller tensioner. In order to reduce the amount of noise emitted by the chaincase, a heavier weight oil and vibration damping material were added. To reduce the noise made by the roller tensioner, it was replaced by a Vespel® tensioner as seen in Figure 7. The Vespel® block spreads the load of the chain over a greater area and has a shallower profile than the roller, decreasing the impact noise of the chain.

Figure 7: Vespel® Chain Tensioner

Another source of noise is the interaction of the idler wheels and the track. As the snowmobile moves, the idler wheels found on the skid frame roll over the inner surface of the track. On a conventional snowmobile track, idler wheels receive an impact load from the lugs and fiberglass reinforcing rods molded in the track. This loading scenario creates a distinctive sound frequency that can be reduced or removed by removing excess idler wheels. A tradeoff to removing idler wheels is increased wear on the slides when encountering marginal snow conditions. To offset this, Hiperfax slides were used on the skid frame as previously mentioned.

Since a variable ratio belt transmission is required by competition rules, noise emitted from the clutches created a unique problem. As the clutch engages and disengages, the driveline creates high frequency noise. Air disturbance caused by the high RPM of the clutches is a major cause of noise emissions. Since the use of a variable ratio belt transmission could not be avoided, the noise it creates must be absorbed by the sound material that lines the hood and belly pan.

Another source of noise that was addressed was the noise created by the CVT clutches. From a noise analysis it was discovered that the primary clutch makes a large amount of noise from the clutch spinning through the air. In order to limit this noise, plates are incorporated in the driven clutch design to make it more aerodynamic when rotating at high speeds.

MATERIALS USED FOR NOISE REDUCTION

For effective noise control both a damper and an absorber must be used. Individually they do not result in optimal noise reduction. The ability of a material to damp structure-born sound is measured as the acoustic loss factor “n.” The acoustic loss factor quantifies the vibration energy that is converted to heat rather than sound. An undamped, 1mm thick steel panel has an acoustic loss factor of roughly 0.001 at 200 Hz. Dynamat Xtreme® applied to a 1mm thick steel panel increases the loss factor to 0.417 at 20°C and 200 Hz. Dynamat Xtreme® was used as a sound barrier and vibration damper. Dynamat Xtreme® was placed as a base layer throughout the hood, belly pan, and the tunnel. Dynamat

Xtreme® is a lightweight, elastromeric, butyl and aluminum constrained-layer vibration damper. [2]

For the absorbent layer, one inch Polydamp® Melamine foam with adhesive backing was used. Polydamp® Melamine foam is an extremely lightweight, open-cell material that exhibits exceptional resistance to heat, low flame propagation and smoke. The Polydamp Melamine® foam was more economical, durable, and easier to work with than fiberglass based sound absorbing materials. The effectiveness of acoustical foam is dependent on the foams ability to convert sound waves into heat energy. The affects of the sound absorbent material can be seen in Figure 6. The 0.002" aluminum skin on the Polydamp® gives it outstanding fire resistance capable of withstanding temperatures up to 425 ºF, which protects the hood and other components from excessive heat. [3]

Another reason for using the Dynamat and Polydamp products for noise reduction was the weight. Weight is a factor when making almost all decisions for a vehicle such as this snowmobile. The Dynamat Xtreme has a weight of 0.45 pounds/ square foot, and the Polydamp Melamine Foam has a weight of 0.05 pounds/ square foot, which is less then half the weight of traditional materials that have been used in the past.

To effectively reduce the amount of noise emitted from the engine compartment of the snowmobile, a combination of both Dynamat Xtreme and Polydamp Melamine Foam was used. This combination of sound absorbing material and vibration dampening material produces optimal sound reduction. These materials were applied to all inner surfaces of the hood and belly pan.

To reduce the vibrations transferred through the tunnel, Dynamat Xtreme was applied to these surfaces. Polydamp could not be used in this location due to the limited space and exposure to snow and dirt.

APPROACH AND ENGINE SELECTION

Choice of engine plays a large role in the design strategy. Both the two-stroke engine and the use of a four-stroke engine were considered. For many, the four-stroke engine is the first choice because of the lower emissions. This is a common reaction because the four-stroke cycle controls the exhausting of combustion gases and the induction of the fresh air/fuel charge more efficiently than that of the two-stroke. However, the four-stroke engine has a lower power to weight ratio when compared to a two-stroke. For comparison between two-stroke and four-stroke outputs, it would take an 800cc four-stroke engine to provide the equal horsepower as a 550cc two-stroke. [9]

A two-stroke semi-direct injected (SDI) engine was chosen over an ordinary carbureted two stroke engine because of its low emissions, performance, fuel economy, and reliability. Semi-direct injected engines are the future of the snowmobile industry by merging the characteristics of two strokes and four stroke engines. A SDI engine unifies the low emissions and fuel economy of four-stroke engines with the lightweight and high performance of two-stroke engines. Along with these qualities and the proven reliability of the Rotax 2-Tec SDI 600cc engine, this engine proved to be our 2006 competition engine of choice.

FUEL CHOICE

The team decided to use the fuel choice with a blend of eighty-five percent ethanol and fifteen percent premium gasoline (E85). E85 fuel choice is an option this year and through research into the necessary alterations needed our team chose E85 to prepare and develop expectations for years to come when the E85 fuel choice is not optional.

FUEL SYSTEM

The major goal of the team this year was to make our Rotax 600 SDI run on E85. Running E85 meant an entire fuel conversion was required which involved extensive research on E85 as well as the SDI fuel system. After some research it was discovered that a 30% increase in fuel spray was required and the pulse of the injectors would have to be carefully calibrated. For help with the fuel mapping, the team turned to Full Flex International. [12] The kit works with all the engine sensors and does not bypass the ECM (engine control module). Each of the engine's four injectors are independently controlled by the Full Flex unit which changes the duration of the injection depending on readings from the throttle position sensor, crank position sensor, knock sensor, atmospheric pressure sensor, and ambient temperature Figure 9. Using the Full Flex kit the snowmobile's engine can be ran on gasoline, E10, E85 any combination.

Figure 8: Full Flex control module.

Figure 9: Full Flex kit connected to injectors

Figure 10: Rotax 2-Tec SDI 600 engine

THE ENGINE

Our Rotax 2-Tec Semi Direct Injected (SDI) engine choice, Figure 10, utilizes a 72mm bore and a 73mm stroke with 46mm throttle bodies to provide optimum performance within the 600cc displacement limit for 2-strokes. The Rotax 2-Tec SDI engine excels in many areas of the 2007 Clean Snowmobile Challenge competition. The SDI engine provides the same horsepower as traditional carbureted engines. The SDI engine delivers a 50% decrease in emissions and a 25% increase in fuel efficiency compared to a carbureted two stroke engine. The 594.4cc motor uses two injectors in each of the two cylinders to deliver the right amount of fuel into the transfer ports. The SDI engine can reduce emissions by ~50% by operating only one injector at idle or low speeds. When the snowmobile is running at high speeds, the electronic control module (ECM) activates the second injector. Along with controlling the injectors, the ECM examines the incoming data from the crank position, atmospheric pressure, throttle position, ambient temperature, and exhaust gas temperature. From this information an adjustment to the timing, injection, and exhaust valve movement is made. All of this information is computed by the ECM to provide response to driver input as well as better fuel economy. [10]

To aid in the combustion process of burning E-85 which has an equivalent motor octane rating of 105-110 and an octane blend rating of 125 a RK Tech head was installed, which has hemispherical domes cut to 14.1 to 1 to accommodate the 105 octane rating. This head is also proven to increase fuel mileage, horse power, and engine cooling due to its drastically improved combustion process as seen in figure 11.

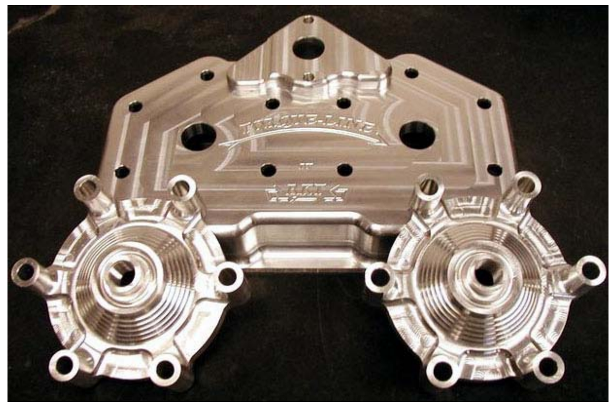

Figure 11: RK-Tech Head

THE EXHAUST

One main area of concern in preparing for the 2007 Clean Snowmobile Challenge was the exhaust system. This system has a huge effect on both the noise level of the snowmobile as well as the emissions. Since these two criteria are weighted the heaviest at competition, the exhaust system was given special attention. The final configuration consisted of a custom internal stinger pipe, a small double core silencer, and a modified large volume Bombardier silencer.

This year the team decided to go a different direction with the exhaust system in effort to make the 600 two-stroke meet the noise requirements. In previous years we had problems with the catalytic converter plugging up due to exhaust packing blowing out of the silencer, to solve this problem the catalytic converter was placed right after the expansion chamber. This eliminates the chance of the packing within our silencer blowing out and plugging the small cells within the catalytic converter. With the catalytic converter closer to the exhaust ports, an earlier “light off” was achieved. With the catalytic converter being under the hood, it was necessary to have a custom pipe built to fit the couture of the chassis as well as accommodate the catalytic converter. AAEN Performance helped us achieved our goal as seen in Figure . Within the expansion chamber, pressure waves from the exhaust process bounce back and forth; these waves can have a great deal of effect on the performance of the engine. A slightly negative pressure is desirable at the time of the exhaust port opening to aid in the blow-down process. A positive pressure is desired during the crank angle between the closing of the intake ports and the exhaust ports. This positive pressure ensures that the fresh charge stays in the cylinder for combustion.

Beyond the initial expansion chamber the exhaust flows into the catalytic converter then into the double core silencer. In the double core silencer, the sound waves are broken up when passing through a special multi-baffled center core into a second chamber. The second chamber has a larger heavily perforated core backed up with a thick layer of high density long strand packing material. The result is a lightweight muffler as see in figure 12. After the double core silencer the exhaust is run out under the gas tank to a large volume silencer as seen in figure 13. The large volume silencer is a modified Bombardier silencer cut to fit and repacked with new exhaust packing as shown in figure 14.

Figure 12 Double core Silencer

By having the catalytic converter under the hood, the temperatures that are trapped under the hood are an issue of concern. The heat temperatures were controlled using custom made aluminum heat shields which completely enclose the catalytic converter. An air baffle system and fan to pull outside air between the heat shield and the catalytic converter was installed. To force additional air to cool the exhaust system an air scoop was constructed on the hood.

Figure 13: Pro-X with Modified Exhaust System

Figure 14: Silencer number two

Figure 15: Custom AAEN Pipe and Expansion Chamber

The purpose of the catalyst is to convert hydrocarbons (HC), carbon monoxide (CO), and nitrogen oxide (NO_x) into water, carbon dioxide (CO_2) and hydrogen (H). This process involves chemical reactions between the catalyst material and the exhaust entering the catalyst. The material on the surface that makes these conversions possible is: alumina oxide, cerium oxide, rare earth metal stabilizers, and the precious metals platinum, palladium and rhodium. [3]

The same 4.66-inch diameter catalyst with a cell density of 400 cells per inch was selected again for this year to prove the durability of the sub substrate can withstand the abuse of a dirty two-stroke. Previous to this year's competition, the catalyst has an estimated 600 miles of use, but with newer technology, this catalyst is rated for 2500 miles. This design was used in order to meet the required flow rates and allow for enough surface area to complete the reactions. The catalyst uses a ceramic substrate, this allows for higher temperatures in the catalyst without the substrate failing.

With the use of the ceramic substrate there has to be an isolation layer between that and any metallic housing. This is necessary due to the fact that the steel housing and the ceramic substrate have different coefficients of thermal expansion. As the temperatures in the catalyst increase the steel expands at a quicker rate then the ceramic substrate. If these two were directly connected the stresses from this expansion could cause the substrate to crack.

For this layer a catalytic converter insulation material was used. This material is especially designed to have optimal mid to high temperature operation. Its purpose is to isolate the substrate from the housing and serve as an insulation to keep the housing temperatures lower. The housing was assembled using a tourniquet style wrap. This is one of the latest advancements in catalyst assembly technology. It assembles the housing and mat to a given pressure, which automatically makes up for any variations in the substrate and the mat material. This is all accomplished by closing to the housing to given pressure instead of a set dimension as with most catalyst assembly practices. This type of assembly allows the converter to withstand accelerations up to 75g for the entire life of the vehicle. The catalyst housing is made of stainless steel, 409 on the conical sections, and 441 for the remainder. The catalyst and housing can be seen in Figure 16 [9]

The catalyst used on the Pro-X is divided into two separate substrate bricks, with secondary air injection between the two bricks. The first brick has a three-metal washcoat: platinum, rhodium, and palladium. This brick is designed to be an extremely effective at reducing NO_x as well as beginning the conversion of the other exhaust gases that are present. The second brick has a palladium and rhodium washcoat. This is used to clean up the emissions, effective on HC and CO emissions as well as finishing the NO_x conversion. Rhodium is the best of the precious metals to help in the conversion of all three major raw exhaust gases; therefore the second brick has an especially high concentration of rhodium. Rhodium is also the least costly of the precious metals used in catalytic converters. The basic layout and workings of the catalytic converter can be seen in Figure 6. [9]

Figure 16: Catalytic Converter

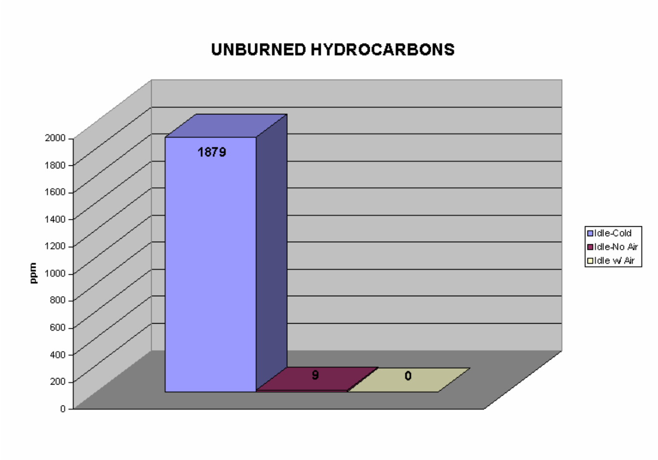

Figure 57: Hydrocarbon Emission Data

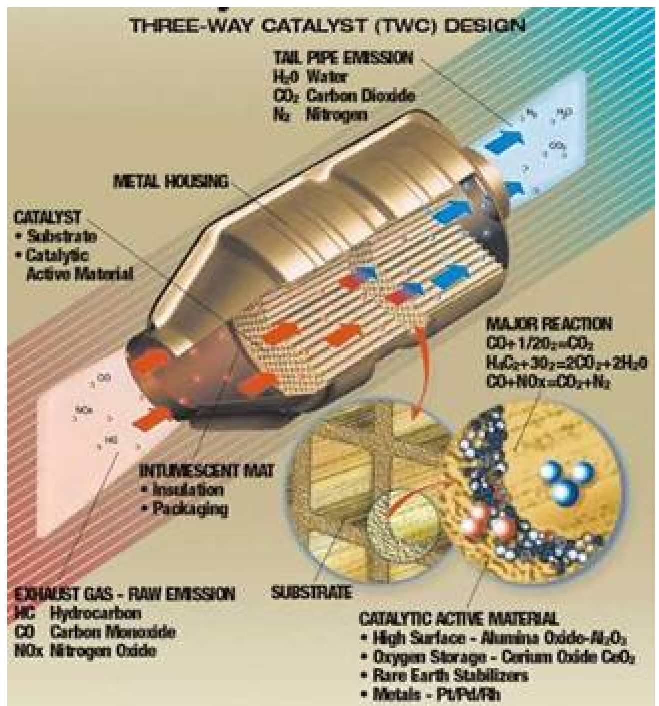

Figure 6: Structure and Function of a Catalytic Converter

To increase the effectiveness of the catalyst, a secondary air injection system was installed (**Error! Reference source not found.**18). The secondary air injection had a large effect on both the unburned hydrocarbon and carbon monoxide emissions as can be seen in Figure 17 and Figure 20. This data was collected using a three-gas analyzer with the snowmobile running at idle, 2000 RPM, with no load. This system consists of an electric air pump to regulate the amount of air that flows into the exhaust system. Oxygen is needed in the chemical reaction that takes place in the catalyst. When the exhaust exits the cylinder after the combustion process there is little oxygen left for the reaction in the catalyst. Additional oxygen is needed to turn carbon monoxide into carbon dioxide and finish the combustion of the hydrocarbons as seen in Figures 17 and 20. The secondary air injection system increases the amount of oxygen available for the conversions in the catalytic converter by injecting fresh air. The effects are most apparent when looking at the carbon monoxide emissions levels (Figure 20).

$$CO + \frac{1}{2}O_2 \longrightarrow CO_2$$

$$H_4C_2 + 3O_2 \longrightarrow 2CO_2 + 2H_2O$$

$$CO + NOx \longrightarrow N_2 + CO_2$$

Figure 19: Typical Chemical Reactions in a Catalytic Converter

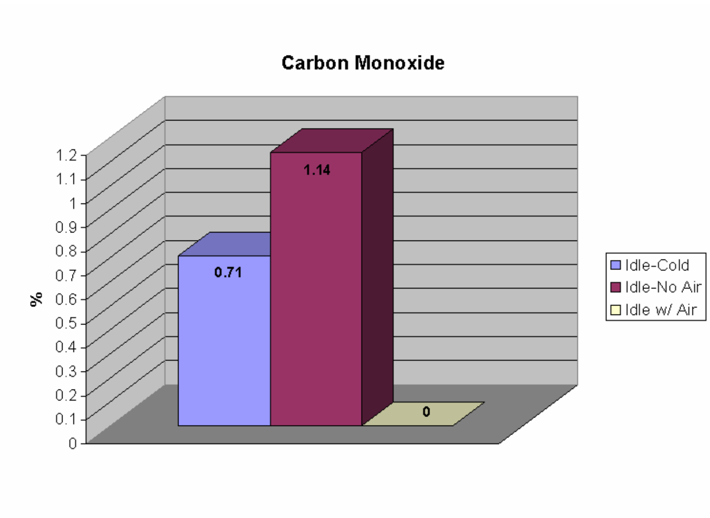

Figure 20: Carbon Monoxide Emission Data

Figure 21: Black Local Section of Failed Catalyst Wash Coat

Figure 22: Cut-Away Section of Catalyst Housing

Figure 23: Functioning Catalyst with Air Injection Diffuser

RIDER COMFORT

The New Trails X-Flex seat, figure 24, is hollow the length of the seat by utilizing a polymer arch to act as a "spring" between the rider and the tunnel. The engineered spring along with the vertical slots make a structural skeleton to deflect and absorb the blow when the snowmobile runs over uneven terrain (similar to the leaf spring suspension on trucks). The seat can give the rider between five to eight inches of travel depending on terrain. The polymer skeleton is covered with closed cell foam for rider comfort.

Figure 24: NT X-Flex Seat

The suspension spring rate and damping was reduced to lower the shock input to the rider over small bumps. The front springs were reduced to an 85 lb/in spring and the damping was reduced to position 1 on the clickers. The front and rear shocks in the rear skid frame were also set for the lowest damping on the clickers. Rear torsion springs were held constant because they were already the same rate as the trail touring suspensions. The front spring however was decreased to a spring with a rate of 120 lb/in.

A computer simulation of the revised spring rates shows the reduced acceleration input as felt by the rider over 3-inch bumps. Our revised suspension calibration is modeled to the left of factory specifications in Figure 25.

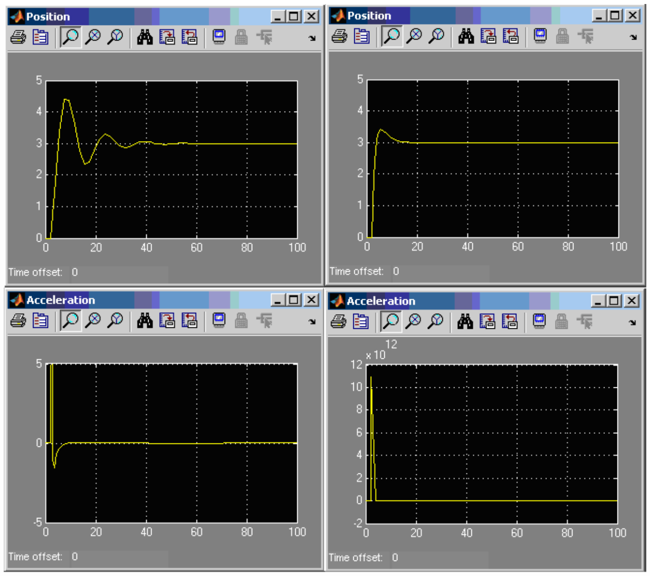

Figure 25: Comparison of DampingCoefficients

COST ASSESSMENT

The 2007 UWP Clean Snowmobile team sought to develop a cost effective solution that could easily be implemented into full-scale production. The major modifications to our snowmobile include the addition of sound abatement, an air pump and a catalyst. It was the goal of the team to be able to produce a competitive snowmobile that would be available to the consumer at a relatively low cost. If the cost of an environmentally friendly snowmobile is too high consumers will not spend the extra money. The snowmobile industry will not be able to sell environmentally friendly machines if they cannot be achieved at a cost that is reasonable.

CONCLUSION

Modifying a 2002 Polaris Pro-X 440 for the 2007 SAE Clean Snowmobile Challenge presented many challenges to the UWP team. The goal was to produce a snowmobile that is both rider and environmentally friendly, as well as maintaining or improving performance characteristics. This has been accomplished in a cost effective manner that has not included extravagant new engineering that would lead to increasing manufacturing costs.

Team UWP is very confident in the design decisions made throughout the modification of the Pro-X. This student team is certain that this snowmobile will meet or exceed all expectations and regulations set by the 2007 SAE Clean Snowmobile Challenge. UWP believes that the modifications made to this Pro-X are the keys to pleasing the general public by making snowmobiling both an environmentally friendly and exciting sport.

References

1. 2007 Rules Committee, The SAE Clean Snowmobile Challenge 2007 Rules. Warrendale, PA: The Society of Automotive Engineers (SAE). 2006
2. Dynamical Control, website, www.dynamat.com. 2003
3. Polymer Technology, Newark, DE. 2005
4. OMG website, http://www.dmc-2.com/BUProd/automotive_catalysts/products/catalysts_for_gasoline_engines/default.asp. 2003
5. Blue Marble website, www.phosfamid.com/html/technologies/index.html
6. Olav Aaen, Clutch Tuning Handbook. 1986
7. Hiperfax, www.hiperfax.com. 2005
8. Marco Nuti. Emissions From Two-Stroke Engines. Society of Automotive Engineers, Inc. 1998
9. Midgley, Mark W. V-Converter Corp. 03/02/04
10. Ski Doo, website, www.skidoo.com. 2005
11. Heisler, Heinz. Vehicle and Engine Technology. 2nd edition, Society of Automotive Engineers, Inc. 1999
12. Full Flex International, website, www.fullflexint.com

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