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ABSTRACT

A student team from Minnesota State University, Mankato’s Automotive Engineering Technology program entered the Clean Snowmobile Challenge 2000. A 1998 Polaris Indy Trail was converted to indirect fuel injection running on a computer controlled closed loop fuel system. Also chassis, exhaust, and hood design modifications were made. The snowmobile was designed to compete in eight events. These events included acceleration, emissions, hill climb, cold start, noise, fuel economy/range, handling/driveability, and static display.

The snowmobile modifications involved every aspect of the snowmobile with special emphasis on emissions and noise. Laboratory testing led to the final design. This paper details the modifications and test results.

INTRODUCTION

The Clean Snowmobile Challenge 2000 was a vehicle design competition for college engineering and engineering technology students. The goal of the competition was to redesign a 1998 Polaris 500 Indy Trail snowmobile (Fig. 1) that would not only have lower exhaust emissions, be quieter, and have better fuel economy, but also meet or exceed the public’s expectations for handling and performance. Seven North American colleges and universities were selected to be included in the competition. Selection was based on student design proposals. Minnesota State University, Mankato, was one of the seven schools selected. The competition was held March 28 – March 31, 2000 at Jackson Hole, in Jackson, Wyoming, and concluded a one-week testing period.

Minnesota State University, Mankato, (MSU) is located in southern Minnesota and is one of seven state universities in the Minnesota State Colleges and Universities (MnSCU) system. Approximately 13,000 students attend the comprehensive university. Automotive Engineering Technology (AET) is a four–year Bachelor of Science program located within the College of Science, Engineering and Technology. The program is accredited by the Technology Accreditation Commission of the Accreditation Board for Engineering and Technology (TAC-ABET). In the fall of 1999, the program had 132 majors and a 1999-2000 graduating class of 31 and Minnesota State’s student branch of the Society of Automotive Engineers had 53 members.

Each student in the program is required to complete a comprehensive senior design project. A group of seven seniors chose the 2000 Clean Snowmobile Competition as their capstone experience. Work on the project began in the fall of 1999, when the proposal was written and submitted by the team. The proposal was accepted by the event organizers on September 18, 1999, and the process of planning, designing, prototyping, testing, and converting the 1998 Polaris began.

Figure 1: MSU Snowforce 500

The team purchased a 1998 Polaris Indy Trail snowmobile with 10,302 miles on it from Grand Teton Resort in Wyoming. Using the comprehensive rules, which had been established to address the controversy over snowmobiles in Yellowstone National Park [1], and for the competition, a systems approach was used to determine the modifications of the snowmobile. The competition rules and scoring structure served as the criteria against which all decisions on modifications were made. Compromises were made between performance, noise, fuel economy, emission levels, durability, and cost using the systems approach.

ENGINE SYSTEMS

The first decision the team had to make was the type of power plant to be used for the snowmobile. Four-stroke cycle and two-stroke cycle engine configurations were considered. Design decisions were also made in fuel metering, emission control, noise control and fuel economy.

FOUR-STROKE VS. TWO-STROKE

A 500cc, liquid cooled, two-stroke cycle, variable exhaust engine manufactured by Polaris was selected as the power plant for the snowmobile. The decision was made after evaluating both types of engines against the following criteria.

Emissions

The hydrocarbon (HC) emissions of a two-stroke engine may be well over ten times that of a four-stroke engine, but carbon monoxide (CO) and oxides of nitrogen can be easily controlled with air injection, according to a lead engineer working on two stroke applications at The Toro Company [2]. The use of a closed loop fuel system, catalytic aftertreatment with secondary air injection has been implemented to dramatically reduce HC and CO emission levels in two – stroke engines [3,4]. HC emissions were the most difficult to control. However, in cold weather conditions CO levels are often more of an environmental problem than HC emissions.

Noise

Noise levels are easily controllable on a four-stroke cycle engine due to the fact that they are less sensitive to increased backpressure [2]. The lead engineer at The Toro Company indicated a reduction of noise levels with the incorporation of a catalytic converter in the silencer assembly. Aerodynamic modifications to the hood and side panels, along with sound deadening materials, have also been utilized to lower noise levels.

Performance

Two-stroke engines have generally been able to achieve their power with a wider and more desirable power band than four - stroke engines with the same displacement. Also, two-stroke engines can be more efficiently made in lightweight form. Four - stroke engines have more parts, are more complex and without the use of exotic materials will always be heavier.

Cost

A survey of engineers working in both two-stroke and four-stroke engine design and development determined that a high performance four-stroke engine would be 15-25% higher with some estimates at 70% and higher in cost to produce [5]. While the range in cost differences was large, it should be noted that each design was different and volume of manufacturing has a great deal to do with the cost.

Size & Weight

The mass of a two-stroke engine is significantly less than a comparable power level four-stroke engine [3,4]. However, the total package volume, including the exhaust system was usually similar. The two-stroke engine would require a large volume in the exhaust system to make acceptable power, while the four-stroke trades engine block and head size for this volume. The four-stroke engine package size was even larger if displacement was used to match the current power available from two stroke cycle packages.

FUEL SYSTEM

The fuel selected by the team for this competition was E10. This decision was made based on the fact that the higher oxygen content of the fuel would aid in the reduction in CO emission levels.

In general, carbureted engines use no feedback systems for controlling the air/fuel ratio. The feedback system made it possible to improve emissions, specifically CO and to some extent HC. When considering closed loop fuel metering for snowmobile applications the benefits were greater due to the ability to maintain a consistent air/fuel ratio under variable altitudes and weather conditions. Two types of closed loop fuel metering systems were explored.

Direct Fuel Injection

The clear way to decrease HC emissions while increasing performance cited in the literature [5,6,7,8] was direct fuel injection. In a carbureted two-stroke engine up to one-third of the air-fuel mixture exited the exhaust port without going through the power stroke. Direct fuel injection is desirable because fuel can be injected after the exhaust port is closed, [5,6,7,8] significantly reducing this scavenging effect.

Two basic direct injection systems were considered. The first system evaluated was Orbital’s Direct Injection system and the second was the Ficht Injection system developed by OMC.

Orbital’s Direct Injection used a prechamber and sonic air blast provided by an auxiliary air pump to finely atomize the fuel and inject it into the combustion chamber. This system used a driven air pump to supply the air blast and automotive style solenoid actuated fuel injectors to deliver the fuel into the air stream. The system utilized more individual parts, which made it more difficult to incorporate into an existing design.

The OMC Ficht Injection used a small solenoid driven piston pump to produce high pressure that atomized the fuel and forced it into the combustion chamber. Fuel was delivered to the injector with a low-pressure pump and the piston increased the pressure to a level that allowed it to enter the combustion chamber under high cylinder pressures.

After researching both systems, the OMC Ficht Injection was selected because of simplicity, cost and reduced weight. In addition, Polaris already used it on selected personal watercraft.

Once the Ficht injection system was selected, more research was conducted on the specific measurements of the system. This included two trips to Polaris's manufacturing plant in Osceola, Wisconsin, where the personal watercraft engines utilizing Ficht injection were built.

Three significant technical issues were addressed to incorporate the Ficht system into the snowmobile. The first was that the injector (Fig. 2) would not allow the engine to run over 6500 RPM due to its ability to completely open then close before it would have to open again. In addition, the injection system voltage requirement was between 38 to 45 volts. The third issue to be resolved was the combustion chamber shape. The chamber had a deeper dished area to make room for the injectors, which required a redesign of the cylinder head.

Figure 2: Ficht Injector

Addressing the problem of engine RPM and the injectors' 6500-RPM limitations, the team considered using two injectors per cylinder alternating them every other firing. This would have given the engine the ability to run up to 13,000 RPM. The second hurdle of the Ficht injection was having a second stator winding for the 38 to 45 volt system used to run the injectors. Alternator winding shops were contacted to see if they had the capabilities to make a stator, but none of the companies contacted could meet the requirements. The team also explored adapting the stator off the Polaris watercraft to run the Ficht injection. This seemed like a reasonable solution.

A two piece cylinder head design was selected. The design was similar to the original head with the exception of the combustion chamber shape. The original head was digitized and a mold of the combustion chamber was made from a Polaris watercraft engine, and also digitized. Next both drawings were merged to form a complete head. A prototype of the combustion chamber was made (Fig. 3) using a rapid prototype machine and laminate layering technology in the Minnesota State University, Minnesota Center for Rapid Prototyping.

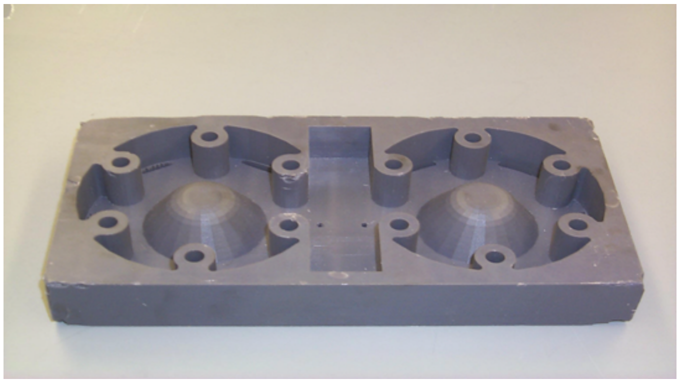


Figure 3: Rapid Prototype Head

Next the injector ports and mounting points were placed in the head drawing. At this point it was discovered that both injectors would not fit since the bolt hole pattern between the cylinder head and the cylinders was in the way. Due to time constraints, designing new cylinders with appropriate bolt patterns to allow for the injectors was not an option. Solutions using one injector per cylinder were briefly explored.

The use of direct injection for lower RPM and indirect injection for higher RPM was discussed. The problem with this set up was that the engine control unit would not support this type of system, also the complexity and cost of a dual system was too high.

The team determined that direct fuel injection was not an option for the first year of the competition. However, they believe they made great strides toward the goal of direct fuel injection for the following year.

Indirect Fuel Injection

Another fuel metering system had to be identified. To address the challenges of reducing exhaust emissions, while increasing fuel economy and performance, the team then decided upon a closed loop system with throttle body fuel injection [5] to accomplish these goals.

Throttle Bodies

The throttle body unit was taken from a 1996 Arctic Cat ZR 500 donor snowmobile. This particular unit was chosen for two important reasons. It utilized automotive style fuel injectors that were available in many flow ranges. In addition no major modifications were required fitting the unit to the application. The throttle body unit (Fig. 4) was also equipped with oil injectors.

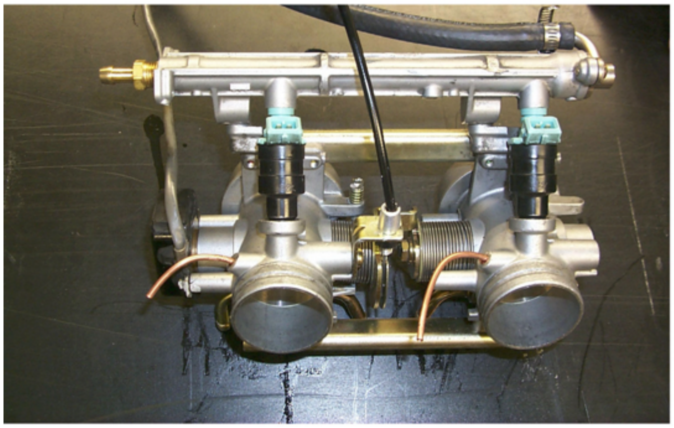


Figure 4: Throttle Body Assembly

Injectors

Two 3/8” magnetic Bosch fuel injectors were used because of their compatibility to the throttle body unit. A wide variety of fuel flow rates were available, which was a consideration during tuning, and would offer a large variety of choices for production models. A flow rate of 15.4 kg/hr was chosen for this application using the following formula based on the power output of the engine and the Brake Specific Fuel Consumption (BSFC):

$$\frac{\text{Power (kW)} \times \text{BSFC (kg/kW} \times \text{hr)}}{\text{Number of Injectors} \times .8}$$

$$15.4 \text{ kg/hr} = \frac{31.85 \text{ kW} \times (.7735 \text{ kg/kW} \times 1 \text{ hr})}{2 \times .8}$$

The injectors were pulsed with an electronic control unit, a valuable component for meeting the goals of this competition. The consistent and even pulses the injectors offered, along with performance and fuel economy gains, gave solutions to the challenges of the competition, while keeping production costs to a minimum.

Fuel Pump and Pressure Regulator

An MSD electric fuel pump (PN 2225), (163 L/hr, at 276 kPa) and Mallory adjustable fuel pressure regulator (PN 4310), (21-448 kPa) were additions to the snowmobile. The throttle body injection required higher fuel pressure than the original fuel supply system could provide. The fuel pressure regulator was required to test different fuel system pressures until the optimum pressure for the fuel injectors was determined.

Electronic Control Unit

A MoTeC M48 ECU was chosen to control the injectors because of its high performance capabilities, versatility, and flexibility. The cost of this unit was approximately $3000.00, which was substantial in this prototype, however, production ECU cost would be approximately $100.00, comparable to common massed produced applications. For the application of the MoTeC system the team used the following sensor inputs:

- Coolant Temperature Sensor
- Crankshaft Position Sensor
- Throttle Position Sensor
- Manifold Absolute Pressure Sensor
- Wide Band Lambda Sensor
- Ambient Air Temperature Sensor

A trigger wheel with 35 teeth 10 degrees apart and one missing tooth was mounted to the crankshaft in the starter recoil housing. The injectors were commanded to pulse when the open space passes the sensor.

EMISSION CONTROL

The emission control strategy incorporated the use of catalytic aftertreatment with an air injection system, and closed loop fuel control. These items were needed to meet or exceed the emission requirements as stated in the rules of the competition [8].

Catalyst

A two-way monolith oxidation catalyst was placed in the silencer section of the exhaust pipe (Fig. 5) to continue the conversion of unburned HC and CO into H20 and CO2. Placement of the catalyst in the silencer instead of the tuned pipe, resulted in little or no changes in the characteristics of the exhaust flow and scavenging effects of the two-stroke cycle.

Two primary concerns were noted with the application of an oxidation catalyst. The first concern was the under hood temperatures caused by the exothermic reaction of higher HC and CO emissions. This potential problem was addressed with the use of a heat shield separating the silencer from the rest of the engine compartment.

The second concern identified was catalyst deactivation caused by excessive thermal loading of the catalyst and oil contamination [9]. This potential problem was addressed by the incorporation of a closed loop fuel system to reduce engine out emissions along with using a smaller amount of synthetic oil for lubrication.

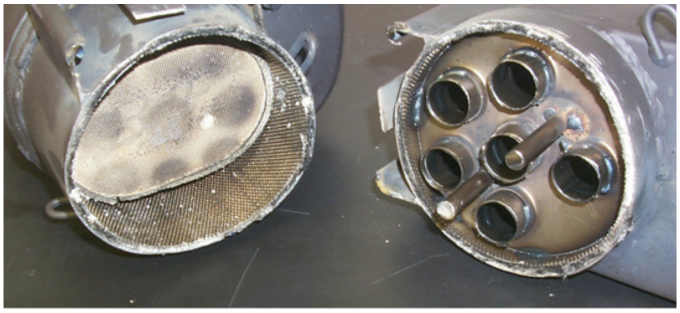


Figure 5: Catalytic Converter and Silencer

Secondary Air Injection

Secondary air injection was incorporated into the exhaust system [8]. This was accomplished by adding a General Motors electric air pump (PN 12562612) to the exhaust system. The air pump allowed airflow into the exhaust stream, which increased the catalytic converter efficiency. By adding more oxygen to the exhaust system, levels of CO were also reduced.

Table 1 and Table 2 illustrate the emission characteristics of HC and CO, first with the air injection pump alone, second with the catalyst alone and third with both technologies implemented.

Table 1. CO Emission Levels

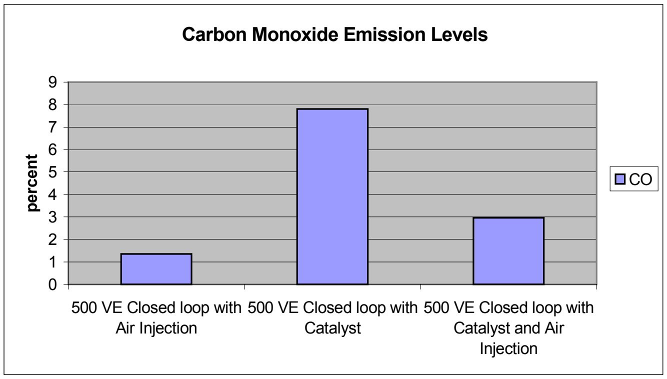
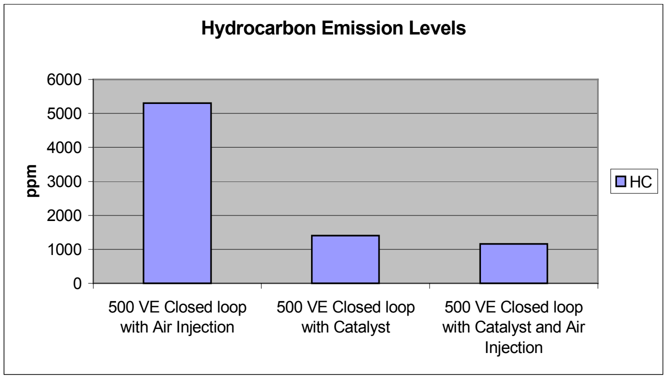


Table 2. HC Emission Levels



Closed Loop Fuel System

The closed loop system that gave the snowmobile greater performance characteristics also contributed to lowering the emissions levels. The closed loop system accomplished this by keeping the air/fuel ratio closer to stochiometric than an open loop system was capable of doing. This allows more efficient and complete combustion of the ideal mixture. In addition, changes in air density caused by varying temperature and altitude conditions are compensated for, resulting in an ideal air/fuel mixture under all conditions.

The production cost of the catalytic converter, air injection system, and closed loop system, would be minimal compared to the reduction in harmful emissions that were seen with the addition of these three items. The components selected are automotive based which has significant economic benefits due to mass production of the components.

NOISE CONTROL

The team faced several challenges in dealing with the noise generated by the snowmobile. Noise coming from the exhaust, intake, and from the engine through the hood vents had to be reduced to an acceptable level based on the criteria stated in the rules for the competition. This had to be done with minimized weight, backpressure gains, or loss of performance.

To control the noise from the exhaust, the team made use of an industry current silencer, which did not originally come on 1998 snowmobiles. A two-way catalytic converter was placed into the silencer, which also reduced noise levels.

To reduce the intake noise, the team incorporated the use of the Polaris Edge air box, which is the quietest air box they produce. The hood and side panels were also redesigned with fewer air vents to eliminate intake and engine noise. This change was made possible do to the fact that the engine used was liquid cooled reducing the amount of air that needed to be exchanged under the hood for cooling purposes. Finally, the interior of the hood and belly pan were lined with Dynomat hoodliner, reducing engine, exhaust, intake, clutch, and chain noise.

FUEL ECONOMY

Design changes incorporated to improve the emission and performance characteristics of the snowmobile generally had the benefit of increasing fuel efficiency. The main challenge was to identify those changes that maximize efficiency of the engine and drive train, without losing performance. The team increased efficiency by controlling the air/fuel mixture, reducing friction, and reducing the weight of the snowmobile. In addition, the drive ratios were adjusted to match the most efficient rpm ranges of the engine.

The closed loop operation that helped the team increase performance, and reduce harmful exhaust emissions, also increased the fuel economy of the snowmobile. When compared to non-feedback carbureted models that constantly spray fuel into the intake, the closed loop system can vary the pulse-width of the injectors to maintain a stochiometric air/fuel mixture for ideal combustion.

The team addressed the problem of the friction of moving parts by having the bearings boiled in a friction reducing fluid. This increased the efficiency by reducing friction of the engine and drive train, therefore increasing fuel economy.

Each area of the snowmobile was evaluated and optimized to minimize the overall weight. Lighter skis, a redesigned brake rotor, which reduced rotating mass, rear idler wheels, and a carbon fiber hood and cowling were all used to reduce the weight of the snowmobile. Reducing the mass of the snowmobile increased the fuel economy by decreasing the load on the engine.

To utilize the most efficient engine rpm, the team decided to maximize the clutching potential. A purple spring and 56 gram weights were used in the primary clutch to change the variable gearing of the snowmobile. The chain and sprockets were replaced due to wear. This increased fuel efficiency by utilizing the most efficient engine rpm range.

CHASSIS MODIFICATIONS

Numerous changes were made to the chassis and suspension system of the snowmobile. The replacement of worn driveline components was among the first changes made. Also, new lighter and more robust components were either designed or purchased to increase durability of the snowmobile.

COOLING SYSTEM

The snowmobile originally came equipped with an air-cooled engine. Heat exchangers and the necessary plumbing in order to cool the new engine were installed.

FRICTION MODIFIERS

Friction modifiers from Energy Release and Militech were utilized. These modifiers reduce the amount of friction between metals that come in contact with one another, therefore reducing drag, and conserving energy.

FRONT SUSPENSION

The skis were replaced with C & Pro skis because they were considered the best performing skis on the market by many trail-riders, ditch-riders, and racers. They came with the mounting hardware and eight-inch carbides that offer improved handling and performance. Worn stock mounts were replaced with new ski mounts from Polaris. The original shocks were replaced with Fox shocks because of their performance and dependability. This dampened the ride and made it more comfortable while increasing handling characteristics.

REAR SUSPENSION

Worn rear suspension bushings and shafts were replaced. Friction Fighter shaft and bushing kits in rear and front bushings were used because of their light weight characteristics (1.13-kg reduction) and robust construction. They greatly cut down on friction in the suspension, causing the ride to be better and more responsive.

Larger rear idler wheels (Fig. 6) were designed and manufactured to decrease track angles in the rear. A new 20.32 cm idler wheel replaced the original 15.86 cm wheel. By not forcing the track to bend so sharply, more horsepower was transferred to the ground, increasing efficiency.

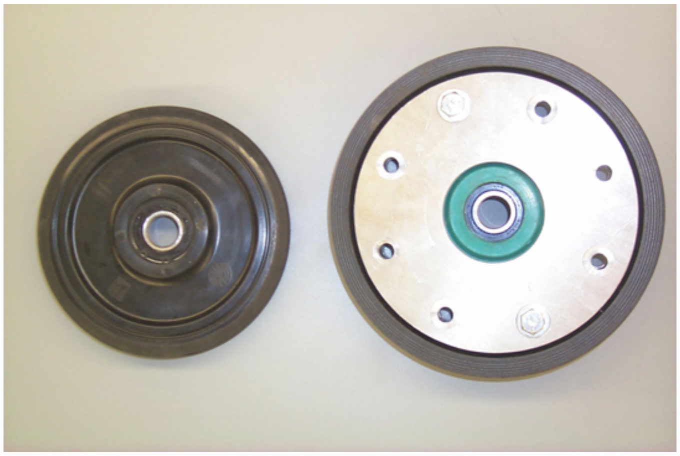


Figure 6: Original Idler Wheel Compared to New Idler Wheel

Before installing the new hyfax plastic on the slide rails, they were heated to just below their melting point. They were then quickly cooled to increase hardness and lower the coefficient of friction.

TRACK

The original 1.91 cm lug track was replaced with a 3.18 cm Camoplast lug track. This was done for three reasons. First, the original track was worn; second, more of the power that the snowmobile produced could be transferred to the ground; and finally for aesthetic appeal.

ERGONOMICS AND SAFETY

Foot and edge pegs were installed to increase ride stability and traction on the running boards. This increased safety for the rider and would cut down on foot or leg injuries.

New handlebars were chosen because they were more ergonomically correct, and offer better performance. All of the controls were mounted directly on the handlebar. This became necessary when the hood line and firewall were modified. This configuration contributed to the safety because the operator's hands did not have to leave the handlebars to use the controls.

BRAKES

A new brake system from Starting Line Products was used to greatly increase the stopping power, and safety of the snowmobile. The new rotor assembly (Fig. 7) was .66 kg lighter than the stock rotor assembly.

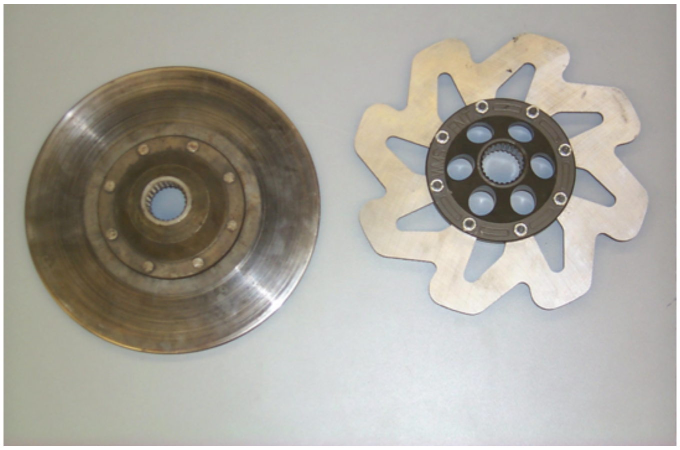


Figure 7: Original Brake Rotor Compared to New Brake Rotor

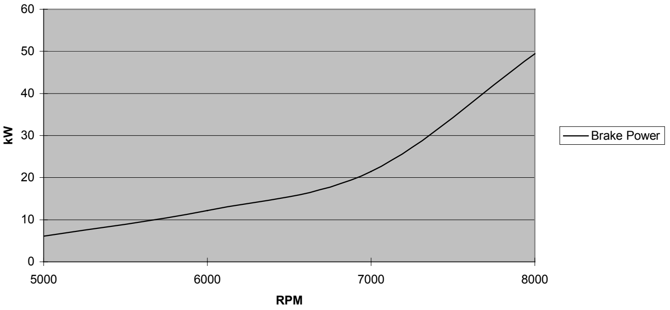
TESTING

Testing of the engine was conducted at the Minnesota Center for Automotive Research (MnCAR) located on the MSU campus. Evaluation included power measurement using a water brake engine dynamometer. All recorded data was corrected using SAE correction factors. In addition exhaust emission characteristics were measured using an OTC MicroGas 5-gas exhaust emission analyzer. This analyzer measured HC emissions in ppm Hexane, and gave CO and CO2 as a percent.

BRAKE POWER TESTING

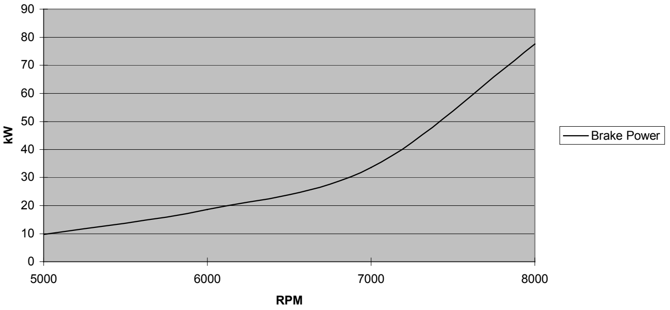
Baseline brake power and torque values were measured on the engine using the stock carburetors and no emission control equipment. The maximum power of 48.1 kW at 7993 RPM and torque of 58.7 Nm at 7815 RPM were obtained (Table 3).

Table 3. Initial Brake Power



Key differences of the modified engine were indirect fuel injection, and monolith catalyst. A maximum power of 77.71 kW at 7,698 RPM, and torque of 96.70Nm at 7,698 RPM were obtained (Table 4).

Table 4. Final Brake Power



EMISSION TESTING

The emission test cycle selected was developed by Southwest Research Institute (SWRI) and the International Snowmobile Manufacturers Association (ISMA) [10]. One hundred percent of the maximum engine speed was determined by the maximum power. Torque values were specified as a percent of the maximum wide open throttle torque observed at 100 percent speed in Mode 1 [10]. The weighting factor was determined by collecting data on four different snowmobiles, operated both on and off trails, with five different driving styles [10]. The test cycle is known as a five-mode steady state test procedure (Table 5).

Table 5. Five Mode Weighting Percentages

Mode	1	2	3	4	5
Nspeed	1.00	0.85	0.75	0.65	Idle
Ntorque	1.00	0.51	0.33	0.19	0.00
Weight, %	12.00	27.00	25.00	31.00	5.00

<u>Emission Testing Procedure</u>

An essential tool for characterizing engine emissions is an appropriate test procedure, based on a duty cycle representative of real in-use operation [10]. A test procedure based on a five-mode duty cycle was used. The test procedure was as follows:

1. Start exhaust ventilation system
2. Warm engine to 80 degrees Celsius
3. Zero exhaust analyzer in dyno room
4. Measure
    a. Barometric pressure
    b. Air temperature
    c. Relative humidity
5. Run test cycle (Table 5)
6. Record the following at each mode:
    a. HC (ppm)
    b. CO (%)
    c. CO2 (%)
7. Repeat step number 5 five times, checking exhaust analyzer filter after each cycle. If results are within 10% variation, average the 5 runs. If results are more than 10% different, run 5 more times and average all results.
8. Using weight percent outlined above calculate total emissions.

The following were the average emission levels recorded over five testing modes (Table 6).

Table 6. Emissions Test Results

Mode	1	2	3	4	5
HC ppm	1615	1767	1037	1082	996
CO %	3.52	4.04	1.95	1.80	2.15
CO2 %	7.72	2.80	2.38	1.94	1.78

Weighting the averages from the results (Table 4), the following values were obtained: HC = 1315ppm, CO = 2.66%, CO2 = 2.968%. Based on the parameters of the competition, the snowmobile was well within the expectations that the competition set forth.

The emission data observed in the lab was significantly lower that the emissions recorded at the Clean Snowmobile Challenge 2000 competition. During the emissions testing portion of the competition the snowmobile developed an over heating problem. This problem was later determined to be a faulty thermostat.

The high coolant temperature caused the MoTec engine controller to go into a “Limp-In-Mode”. This mode of operation significantly richened the air/fuel ratio to protect the mechanical components of the engine but also was detrimental to the engine out emissions of the engine.

OVERALL COST ANALYSIS

The philosophy incorporated for this project was to use technologies that have already been tested and proven. Some of the equipment used such as indirect fuel injection, and having a catalyst in the exhaust system, had been used in the automotive.

TWO-STROKE ENGINE

The durability of the two-stroke engine in the snowmobile market had been widely accepted. The cost of producing a two-stroke engine, compared to almost every other option, heavily weighted the decision for this engine platform, which also complied to the competition rules and scoring structure.

INDIRECT FUEL INJECTION

The snowmobile industry had started to convert from carbureted, to indirect fuel injection in selected models. Indirect fuel injection, controlled by a closed loop system, had been mass-produced in the automotive market and had proven its reliability, while increasing performance and efficiency. Another advantage of this system is that there was no longer a need to re-jet the carburetor for different altitude and climactic conditions, which reduced cost during the life of the snowmobile.

EMISSIONS

A review of the literature [5] had identified catalyst aftertreatment and air injection as the most cost-effective means of reducing HC and CO emissions. These strategies were determined to be acceptable methods for this application.

Catalytic Converter

Designed to last the life of the vehicle, a catalytic converter was easily implemented into this project. The durability and comparatively low cost if mass-produced catalytic converters was a definite advantage for controlling emissions.

Air Injection

When used with a catalytic converter, air injection greatly reduced the HC and CO emissions of the snowmobile. This component could be implemented into the exhaust system at little additional cost, especially compared to the advantages it offered for emission control.

CHASSIS

Having a chassis that performed well under a variety of conditions, along with being light and efficient was a necessity. Modifications could have been less for a production snowmobile, however for a prototype model aesthetic appeal was achieved through the use of custom built and low volume components.

Friction

Many of the components of the chassis were replaced due to wear. Components that were worn were replaced with equipment that reduced friction, and coated with friction reducing agents. These items could have been installed in a production model with minimum expense.

Ergonomics and Safety

Additions addressing ergonomics, including moving the controls to the handlebars, were done not only for comfort, but also for safety. While cost may be slightly more for production, this could also increase the sales of a particular model due to its safety features. This has been seen in the automotive market since the development of added safety features have become available.

Clutching and Gearing

Different springs and weights were utilized in this project to maximize the efficiency of the snowmobile. These items could be installed in a production model for no additional cost to the manufacturer. The original clutch housing could be used while installing springs and weights of different rates.

CONCLUSION

From a technical standpoint, the Clean Snowmobile Challenge 2000 proved that a stock snowmobile could be modified to operate quietly, and efficiently, while still retaining good performance characteristics. With the additions of closed loop indirect fuel injection, and catalytic aftertreatment, significant strides in emission and noise related problems could be made. Efficiency, handling, and ergonomics were also improved with chassis modifications.

From an educational standpoint, the “real” goal of this project, and the Clean Snowmobile Challenge 2000, was to provide an opportunity for learning. Learning not only involved the technology aspect, but communication, time and budget management, and teamwork. This team knows that this goal has been successfully achieved.

RECOMMENDATIONS

Based on the experience gained through this project, the team specifically recommends that:

- Government, industry, and education continue to help solve the controversy surrounding snowmobile use in environmentally sensitive areas.
- Industry, government, and other groups continue to provide opportunities such as the Clean Snowmobile Competition 2000.
- Colleges and universities continue to commit resources, (funding, personnel, space), to enable entry into these types of competitions.
- Future engineering and engineering technology students take advantage of the opportunities provided.
- Present students, involved in these competitions commit themselves to support future educational opportunities such as these competitions provide.

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