2006 SAE Clean Snowmobile Challenge

UNH Clean Snowmobile Team

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ABSTRACT

The five members of the University of New Hampshire Clean Snowmobile Team set out to design a high performance, environmentally friendly snowmobile to compete in the 2006 Society of Automotive Engineers Clean Snowmobile Challenge. Being a first year project, the 2006 team members had realistic goals to enter in the 2006 CSC on a limited budget. The goals of the competition were to re-engineer an existing snowmobile to reduce emissions and noise while maintaining or improving overall performance.

INTRODUCTION

With no prior equipment to begin with, and very little project funding at the university, the 2006 UNH team started with a donated 1993 Arctic Cat Thundercat chassis. While the snowmobile was not complete, it was a good starting point due to its spacious engine bay and solid chassis. The project was broken down into sub systems for organizational purposes. The sub systems were: engine, drive train, chassis, and intake/exhaust.

With only five team members, all members contributed to all aspects by the end of the project. This paper will address design approach the UNH SledCats took to produce a more environmentally friendly machine while maintaining present performance standards set by the snowmobile industry.

Snowmobiling is a very enjoyable experience which many people choose to participate in. Unfortunately, snowmobiles are extremely harmful to the environment from the production of large quantities of nitric oxides (NO_x), hydrocarbons, and carbon monoxides. The majority of snowmobiles manufactured by the industry operate with 2-stroke power plants which are known to produce high levels of pollutants. The reason for the “dirty” combustion of a 2-stroke engine is primarily due to the fact that they run off of a fuel-oil mixture unlike 4 stroke motors which use an oil bath and straight fuel. The fuel-oil mixture is not burned completely, with 20-30% of the mixture leaving the cylinder unburned. The combusted oil products are also harmful substances being let into the atmosphere.

Currently, snowmobile pollution is a serious problem particularly in National Parks such as Yellowstone, where workers were forced to wear gas masks because of snowmobile exhaust. Two-stroke snowmobiles create roughly 240 times the amount of pollution as a well tuned automobile. In a seven hour snowmobile ride, the equivalent of a day of riding, a snowmobile will create as much hazardous pollution as an automobile would create in 100,000 miles of driving. This amount of pollution created by each snowmobile, combined with the rising popularity of snowmobiling created a huge pollution problem that was unacceptable. The EPA and the snowmobile industry have been working together to fix this problem, and have made great achievements, but still more can be done. The SAE Clean Snowmobile Challenge seeks out new and innovative ways to reduce snowmobile pollution while keeping costs low, and performance high, so that people may continue snowmobile without the current environmental side effects.

APPROACH

The UNH Clean Snowmobile Team focused on the three major goals of the 2006 CSC which were to reduce emissions and noise, while maintaining performance. To achieve these goals, the team decided to start with a new power plant for the snowmobile.

Power plant Selection

There were many options to look at when choosing a new engine for the snowmobile. They included:

-2 stroke carbureted
-2 stroke direct or semi-direct fuel injection
-Rotary engine
-Diesel engine
-4 stroke carbureted
-4 stroke direct or semi-direct injection

Two stroke engines are the most commonly found engines in modern snowmobiles because of their high power to weight ratio. The two stroke engine has fewer moving parts which results in an overall lower complexity and weight. However, the benefit of fewer parts unfortunately means drawbacks in other areas particularly emissions. Emissions testing conducted by the Southwest Research Institute describes how 2-stroke engines compared to 4-stroke engines emit 95%-98% more HC, and 85% more CO (1).

Other considerations included rotary engines which produce high power but are extremely complex in their operation due to their unique combustion process. Diesel engines would not be as efficient in a snowmobile due to their robust construction and heavier weight. Also, most diesel engines have high torque outputs with relatively low rpm's which is not a desired characteristic for a high performance snowmobile.

Final Power plant Selection

The UNH team knew the importance of maintaining or improving performance. Therefore speed, acceleration, handling and ride comfort were major considerations which went hand in hand with reducing emissions and noise. With these necessary characteristics in the forefront of the design problem, a 4-stroke sport bike motorcycle engine was chosen as the new power plant for the application. Through research and simple cost constraints, the Honda CBR 600 F4i engine was determined to be the best for the application.

The F4i was Honda's first fuel injected engine. Fuel injection is beneficial due to the fact it regulates the amount of fuel input into the combustion process to meet the requirements set forth by the engine control unit (ECU). Air/fuel ratios can change with engine load to reduce fuel consumption and efficiency. This value is also adjustable using various programs and instruments such as an electronic engine control unit tuner. The F4i also has a California specific model which incorporates a catalytic converter to reduce the emissions for the particular engine. With this catalytic converter, the 2001 engine easily passes the 2004 California Air Resources Board (CARB) emissions standards (2). This catalytic converter is designed for maximum performance and the lowest emissions with the F4i engine and is utilized in the custom exhaust system fabricated by the team.

Before using the engine in the snowmobile, it was disassembled, cleaned and inspected for wear. All carbon deposits were removed from the engine head to ensure proper combustion. Throttle body synchronization was performed at a Honda factory service center for optimal performance.

Custom Drive train

Motorcycles utilize a manual transmission to shift gears for best performance at particular engine operating conditions. The F4i has a primary gear reduction from the crankshaft to the internal transmission of 1.822:1. The stock engine consists of a six speed constant mesh transmission with a maximum gear ratio of 1.13:1. With the combination of the primary gear reduction and the transmission gearing, the maximum output shaft speed of the motor was 6,500 rpm. Typical constant variable transmissions (CVT) operate at rpm's up to 8,500. To increase the output shaft angular velocity, the UNH team stripped the engine of all its shifting mechanisms, and eliminated all but two gears in the transmission. To accomplish this, the large 5th gear sprocket, which is originally on the countershaft, was machined to fit on the main shaft and the smaller 5th gear sprocket, which initially is on the main shaft was machined to fit on the countershaft. Fifth gear previously produced a 25:20 gear ratio, and by switching these gears from the main shaft to the countershaft, the gear ratio was converted to 20:25 increasing the output shaft angular velocity to 9,500 rpm. From the output shaft, the original motorcycle sprocket was machined and welded to a transmission gear from a Chrysler front wheel drive vehicle. The newly machined output gear meshes with an equally sized gear mounted on the custom machined drive shaft. The overall gear ratio from the engine crankshaft to the CVT shaft is 1:1 resulting in a final gear ratio of 1.4576:1. The drive shaft is supported by custom fabricated brackets containing 3 roller bearings to ensure smooth and reliable operation. The end of the shaft is machined with a 30:1 taper to properly fit the CVT. Figure 1 shows the drive shaft modeled in Pro-Engineer, and Figure 2 shows the actual fabricated drive train.

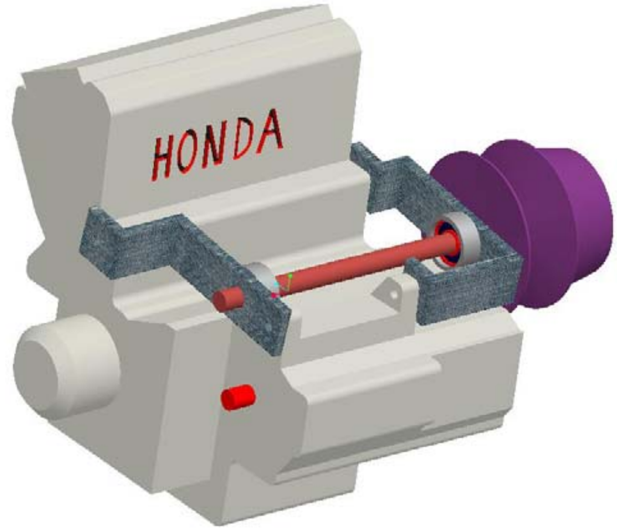

Figure 1. CAD model of drive train.

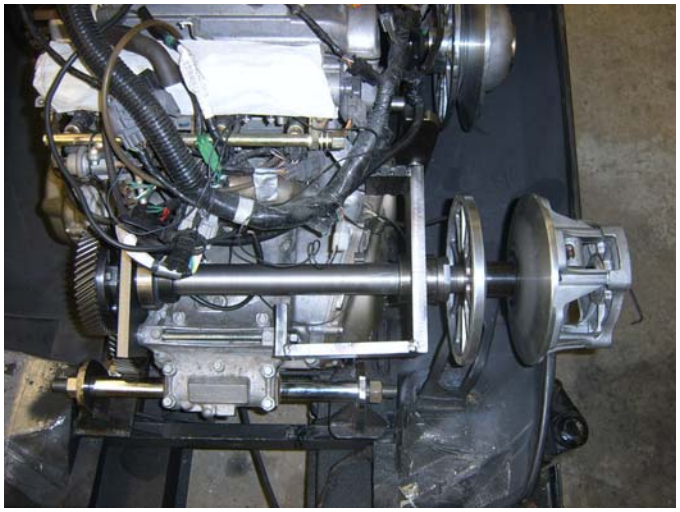

Figure 2. Actual fabricated drive train.

Due to the "up and over" design, the center to center distance between the drive and driven clutches is 18 inches, whereas a normal snowmobile has about a 12 inch span between clutches. The CVT belt from a John Deere Gator turned out to be a perfect fit for the team's application. The motor mounts fabricated by the team are also adjustable by one inch from the front to the rear of the engine bay allowing the engine to slide for proper belt tension.

This custom drive line nearly doubles the output torque of the motor from 45 ft-lb to 70 ft-lb of torque. These carefully calculated modifications produce greater performance out of an already high performance engine. Figures 1 and 2 show parts of the UNH designed drive train.

Exhaust and Air Injection

To properly fit in the engine compartment, the larger F4i power plant was reversed (heads and exhaust ports facing the rear). This allowed for a much simpler exhaust design with fewer bends to reduce backpressure. For emissions control, the exhaust is fitted with the stock California model catalytic converter and an exhaust air injection system. The air injection system takes fresh air from the custom intake and injects it right after the exhaust valves going into the exhaust header. This increases the temperature of the exhaust gases to burn off any unburned hydrocarbons and increases the efficiency of the catalytic converter because of the higher temperatures. The amount of fresh air injected into the exhaust is controlled by the engine control unit via an electronic valve.

For exhaust silencing, a new Honda CBR600RR muffler was used. Since this muffler was designed specifically for the Honda CBR series engines, the resonating chambers and perforation are specifically calculated for maximum noise reduction. The exhaust runs straight from the engine header under the gas tank to the catalytic converter and then to the muffler which is located in the former storage compartment of the snowmobile seat. The rear exhaust outlet decreases frontal and side noise levels while also adding to the aesthetics of the snowmobile.

PERFORMANCE TESTING

Following completion of mechanical fabrications, the snowmobile was brought to the engine testing lab at our engineering facility for dynamometer testing. Using the Land and Sea DYNOMITE, the team performed a WOT dyno test to find the actual torque and horsepower that the engine was producing. Peak horsepower was 123 and peak torque was 72 ft-lb at 8,950 rpm. The maximum rpm of the clutch shaft was 9,417. The torque and horsepower curves can be seen below in Figures 2 and 3.

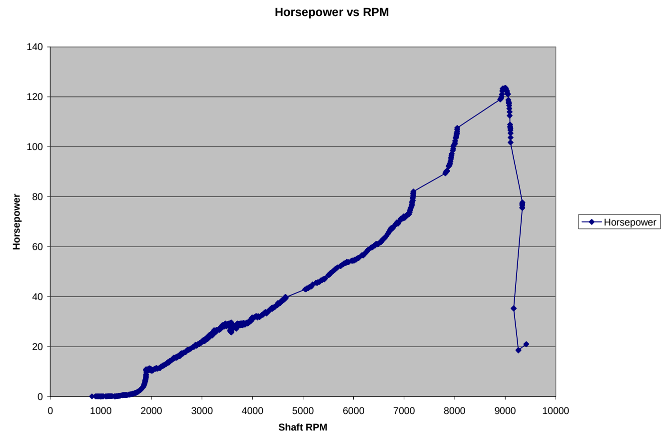

Figure 3. Plot of Horsepower vs. RPM recorded on Land and Sea DYNOMITE

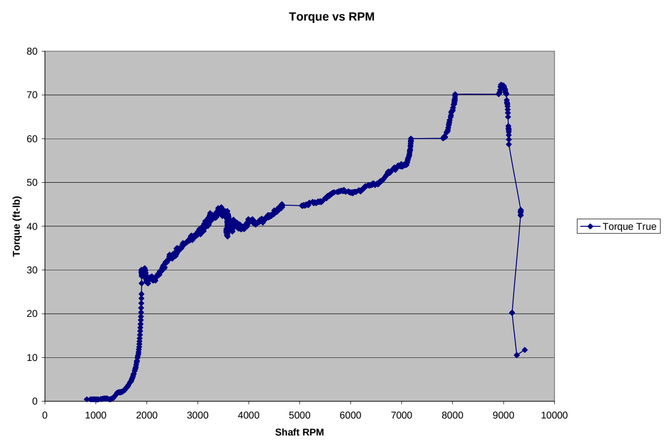

Figure 4. Plot of Torque vs. RPM recorded on Land and Sea DYNOMITE

Figure 5: Dyno testing using Land and Sea Dynomite

COST

The entire 2006 UNH Clean Snowmobile Project was completed on a small budget of only $1900. Almost all parts were fabricated in house utilizing the UNH machine shop. The engine was bought used and the snowmobile chassis was donated to the project. Most of the costs were a result of chassis restoration and modification. Table 1 below shows a breakdown of our costs to complete the project.

Table 1: Cost analysis

Components	Description	Cost
Engine	2001 Honda CBR600F4i	$800
Engine Parts	Computer, Ignition Switch, Kill Switch, Oil Filter, Working Fluids	$283
Chassis	1993 Artic Cat Thundercat	Donated
Chassis Modifications	Brake Parts, Main Shaft, Idler Wheels, Bar Risers, Headlight, Taillight	$214
Exhaust	Honda 600RR Muffler, Tubing & Catalytic Converter (California Model)	Donated
CVT Sub Assembly	Bearings, Gears, Material & Welding	$188
Clutches	Polaris CVT Assembly	Donated
Miscellaneous Costs	Tools, Parts, Hardware, Paint, Fiber Glass Etcetera	$695
Total		$1,900

The majority of the costs were for chassis modification. Since the power plant chosen for the project is foreign to the snowmobile industry, the chassis had to be built around it for best performance in terms of vibration, weight distribution and center of gravity.

CONCLUSION

As a first year project for the University, the SledCats produced a quality snowmobile in a short period of time considering that all custom components were fabricated in house by all the team members with no out sourcing. Our engine emission reduction design consists primarily of a new power plant with a stock catalytic converter designed specifically for maximum emission reduction. Engine tuning and throttle body synchronization provided better performance as well as reducing emissions. The major problem facing the team was modifying the chassis around the new engine, designing a simple yet effective custom drive train for minimal hood reconstruction and chassis modification, and fabricating a custom exhaust for maximum noise reduction.

The team's ultimate goal was to finish the snowmobile in time to compete in the challenge. By completing the design and competing, the Clean Snowmobile project will quickly become a project of high interest comparable to other SAE projects currently in the department. As the team progresses, the project can generate interests in the local communities and industry due to its importance in future environmental concerns.

ACKNOWLEDEMENTS

The 2006 UNH Clean Snowmobile Team would like to thank the following sponsors for their donations and support. Without them, the project would not have been a success.

-Nault's Honda of Manchester, NH
-Argo's Cycle Salvage of Hookset, NH

-HK Powersports of Hookset, NH
-Mark's Motorsports of Enfield, CT
-Andover Corp. of Salem, NH
-Sinful Creations of Deerfield, NH
-Novel Iron Works of Greenland, NH
-UNH Mechanical Engineering Department
-PEB Management of Durham, NH
-AAMCO Transmissions of Portsmouth, NH
-Concrete Impressions of Somers, CT

REFERENCES

1. Lela, C.,White, J.,Haines, H., and Sacklin, J. "Laboratory Testing of Snowmobile Emissions: Southwest Research Institute" Report number SwRI 08.05486. July 2002. Montana Department of Environmental Quality. Helena, Montana, and National Park Service, Yellowstone National Park, Wyoming.

2. "First Ride: 2001 Honda CBR600F4i"; Motorcycle Online Staff; http://www.motorcycle.com/mo/mchonda/01f4i.html

3. "Top Five Snowmobile Myths"; 20-Jul-2005; http://www.bluewaternetwork.org/reports/rep_pl_snow_myths.pdf