The future of the 2-stroke engine snowmobiles

Rémi Surprenant
Alexandre Jutras
Éric Blouin
QUIETS, Ecologic snowmobile ÉTS

Copyright © 2005 SAE International

ABSTRACT

We are very proud to take part in this year's Clean Snowmobile Challenge hosted by Michigan Tech University. We are bringing the same sled we used last year, a 2-stroke 600cc MXZ Rev from Bombardier, with some major modifications. With the experience we have acquired from last year's event, we have come up with some new ideas and are eager to see how good our snowmobile will perform throughout the multiples challenges. In the present technical paper, you will see what modifications we have made and the different reasons why we made them.

INTRODUCTION

Since the creation of the snowmobile in 1960 by J-Armand Bombardier in Quebec, Canada [1], this product knew a quick popularity throughout the country and North America. With an annual average snowmobile sale in Canada of more than 57000 units on the last twelve years, this winter sport as an important economic impact. In Canada only, this sport generates $6 billion annually [2]. This situation is proportionally the same in the province of Quebec. Each year, about 800000 persons practice snowmobiling throughout Quebec and the total direct economic repercussions are estimated at 752 M$ [3].

However, all this circulation involve significant consequences. Since december 1st 2004, the court of Quebec ordered a judgement prohibiting the snowmobiles on approximately thirty-eight kilometers in the Mont-Tremblant area on the linear parc of "Le Petit Train du Nord". This legislation came from complaints of owners, living a few hundred meters away from the path, that consider unacceptable the noise emitted by the snowmobiles everytime of the day [4]. This judgement had big consequences on the snowmobile tourism industry and several jobs are in danger.

To resolve this situation and to assure the survival of the region winter tourism, new technological solutions must be used. Those solutions must provide the enthusiasts with good performances while being environmentally friendly.

Since 1998, to help improve and find innovative ideas for the snowmobile world, the Society of Automotive Engineers organizes each year the Clean Snowmobile Challenge (CSC). This competition is opened to colleges and universities in north america. The goal is to modify an existing standard snomobile to make it more ecological, mainly by reducing its fuel consumption, the levels of pollutants and reducing the noise emitted by the sled. The students must also keep good performances to keep a certain appeal to consumers. This year, the CSC will be held for the 3rd year in a row in Michigan's Keweenaw Peninsula from March 14 to 19. To represent the Quebec, the QUIETS from the "École de Technologie Supérieure" in Montreal will be participating for its second year at this challenge.

The following paper describes in details the modification made to our sled and why we decided to make them. The first section describes how we were able to keep a maximum performance while making important changes. Secondly, the emissions section explains the technologies used to reduce harmful exhaust pollutants. The next section is about noise reduction and the different systems used to achieve our goal. Finally, we present a small analysis concerning the overall costs of all our modifications. In the end, we can see that the sled proposed by team QUIETS is economical, reliable, performant, environmentally friendly and is a good contender in the 2005 CSC.

PERFORMANCE

THE ALTERNATIVES – By talking with snowmobilers, we found which characteristics we were going to focus on when working on our sled. All the people are convinced that the power, the torque and the acceleration of the snowmobile are the most important things. The competition needs us to develop a balance between environment and consumer's demands. How could we make this? First of all, we have to analyze what technologies are available that offer power, that are light weight and have good noise and pollutant emissions.

- Two stroke engine
- Four stroke engine
- Two stroke semi-direct injection engine
- Two stroke direct injection engine
- Diesel compression technology

The 2-stroke engine is the best engine based on power to weight ratio. It has a good acceleration and powerful torque. However, the biggest problem with the two-stroke engine is certainly its level of pollution. The snowmobile emissions test clearly shows that the 2-stroke engine pollutes more than the 4-stroke.

	grams/HP/Hour			
Engine	HC	CO	NOx	MP
2 stroke	111	296	1	2,7
4 stroke	8	123	9	0,2
2stroke DI	22	90	3	0,6

Table 1: Combustion gas chemical composition. [5]

This study presents a different type of engine called 2-stroke DI. DI meaning direct injection. It suggests that this new technology will reduce emission from 25 to 35 percent inferior than those of a 4-stroke engine. This process is now available on marine engines and watercrafts and they surpassed the 4-stroke standards. The 4-stroke has a lot of advantages too. It is reliable and as low pollutant emissions which make it a good choice. After examining all the information for every engine, we decided to base our modifications on the consumer's and environmentalist's demands.

CHOOSING OUR MOTOR – With all these alternatives, to make the ideal choice is not easy. Each engine has advantages and disadvantages. We can base our choice on several different criteria like the pollutant's emissions, average fuel consumption, the noise level of the engine, its reliability or its performance. We needed to take a logical decision that represented today's snowmobile market and choose an engine that represented the choice of the snowmobile owners. This choice could have more impact on bringing technologies further in snowmobile. We prefer this orientation rather than to invent a new engine or to use another form of energy to move this machine. Thus, we discovered in our research that the most popular engine sold in snowmobile these last years is in the range of the 2-stroke 500 cc.[6] With this second criteria, we could eliminate some engines that we talked about earlier. We continued our research and we found a survey that shows the more important aspects that the snowmobilers consider at the time to purchase a news sled. Here are the results of this survey:

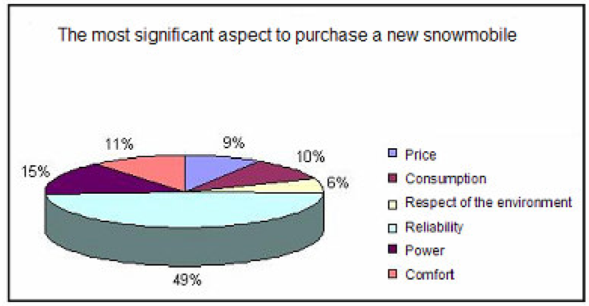


Figure 1: Criteria that guide the consumer's choice for a snowmobile.

However, by taking account only of the two following criteria: power and reliability, there are 2 engines which are dissociated more than the others; the engine 2 times and the engine 4 times. Thus, to make a more exact decision we compared these two engines on the characteristics than we knew about these 2 engines. Here what is come out from these engines [7] :

4-stroke:

- Reliable
- Low power/weight Ratio
- Clean Emissions
- Less fuel consumption
- Harder maintenance
- Present in snowmobiles since 1960
- Quiet
- More advanced technology

2-stroke:

- Less reliable
- High power/weight ratio
- Not very clean emissions
- High fuel consumption
- Easy maintenance
- Present in snowmobiles since 1960
- Noisy
- Simple technology

With this information, the choice of the 2-stroke engine is more favorable since it is this type of engine which one finds more on the market. However, this engine does not really satisfy the criteria of the competition. To support this choice, here is a study [8] that shows the advantages of 2-stroke DI compared with a 4-stroke engine (another possible alternative). This comparison is made with two similar engine operating in the same conditions.

- The 2-stroke engine with direct injection is 30 % lighter, 30 % less expensive, 30 to 40 % less cumbersome and up to 50% more powerful than the 4-stroke engine.

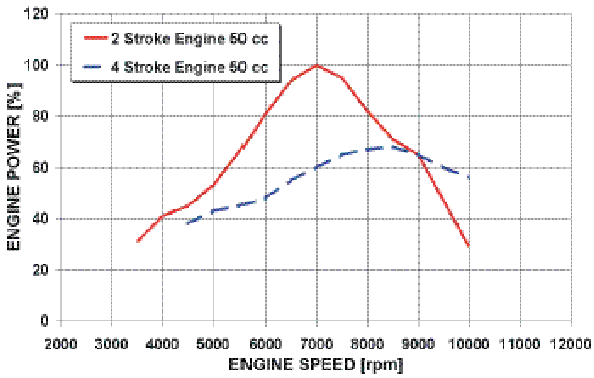


Figure 2: Percentage difference of the effective power of the GDI two-stroke and a series four-stroke engine.

Thus this type of engine offers the following advantages:

- It respects the levels of antipollution regulation at the same cost price as the 4-stroke, even less...

- It becomes more suited than a 4-stroke engine to accept tighter levels of anti-pollution (4-stroke is penalized by its NOx and CO emissions).
- It emits less visible smoke.
- Its fuel consumption is 10 to 20 % smaller than the 4-stroke with of the same carburetor capacity.

Our final choice – Finally, to meet all the criteria that will be used to evaluate the sleds during the CSC, that is, consumption, the pollutant emissions, the noise and the performances and to respect our own pre-established criteria, we decided to use the a Rotax 2-stroke 600 cc HO from Bombardier.

Figure 3: Rotax 600cc two-stroke engine for Bombardier.

However, this is a bold choice of engine. Several studies prove that it is the worst enemy of the environment. Isn't this a true challenge? While making it cleaner? To be able to obtain results known as ecological and in the light of the data showed above, the engine will be equipped with a direct injection system.

INJECTION – All the aspects of direct injection system are complex and choose the right one is very difficult. Thus, we decided to scan the market to find a system that offers all advantages of automotive direct injection system, which can apply on small engine and that it is user friendly. Finally, we found the Synerject system. All of the articles that we found tell about this system that it is the revolution in gasoline direct injection. Here is a picture of the injection system. [9]

Figure 4 : Orbital direct fuel injection module.

This module includes three things; 2-fuel injector (in red), an air rail with a only one entry (hose on the right) and a fuel rail with a entry (hose on the left) and a return (hose on top). The principal part of this assembly, the air injectors are installed under this modulate and these components connect the Synerject modules at the engine. The principle is simple: when the fuel injector receives a signal, it injects of fuel and in the same moment the air injector receives another signal and it injects after the pre-mixed charge in the cylinder of the engine.

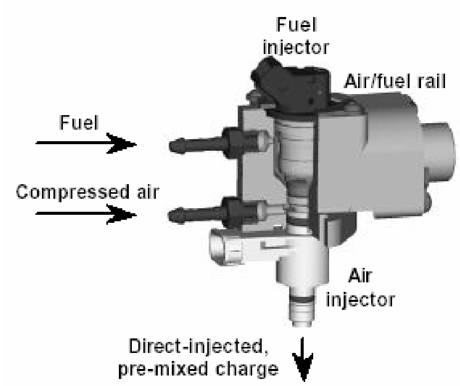


Figure 5 : Cross-section of the Orbital module.

To install this system on a 2 strokes engine is not simple because the totality of the circuit must be review and keep the original performance is difficult .To have more information to install this system we found a schematic that explains in details all of the components that must be modified to accommodate it. See figure XX in appendix. Thus, the major component to modify is the engine's head. The initial position of the spark plugs on our engine is at center of the cylinder (Sees pictures xx). With the Synerject system, the injectors and the spark plug make an angle of 30° with a vertical axe. This new configuration causes a lot of problem to keep the functionality of the engine. To eliminate this problem we decided to design a new engine's head. With design we are sure that the position of the components is right and that the sealing is preserved. Here is the new engine's head:

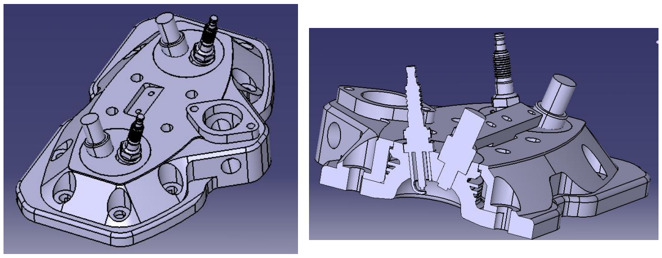


Figure 6: The new engine head design.

To works good, the Synerject system needs to have a fuel pump and an air pump. Each snowmobile that equipped with a 2-stroke conventional engine have a fuel pump but the pressure that it cans delivery is not too high. Thus, we decided to put a secondly pump in series with the original. With this set-up, the pressure that we obtained was very too high for the fuel injectors. We decided to put on the circuit a return directly in the fuel tank to assure to respect the 27 psi pressure recommended by the company. For the air injector, it's a another problem because it is necessary to install a air pump on the snowmobile. In this situation, there are two solutions to correct it: try to find an ideal pump for this application and install it directly on electric system or make a pump with the good size and that works without electricity. Thus, we decided to design an air pump that it works by a pulley and a strap.

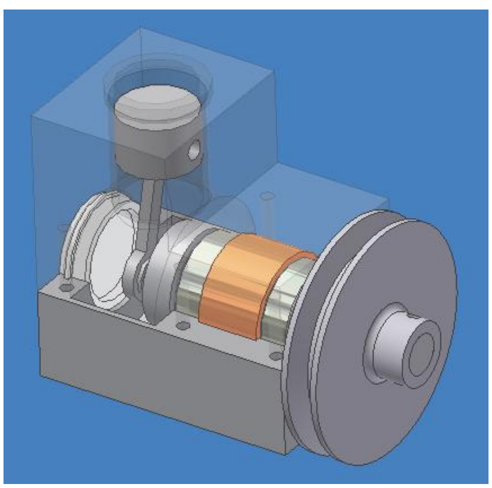


Figure 7: Custom air pump for the high pressure air injectors.

The rotation of the engine assures her operation. In this solution, the air pressure is also too high and we decide to do the same thing that fuel pressure. We have redirected the overflow in the air box of the intake of the engine. With this modification, the pressure is maintaining around 80 psi. In fact, the Synerject system needs around 100 psi to works fine and we have 107 psi.

Finally, to drive air and fuel injectors a computer is necessary. Last year at the competition, we had an injection system drives by a Haltech controller. After research, this controller is correct to drive the fuel injector but it not enable to drive the air injector also. The only solution for this problem is to design an independent electronic circuit that permits to use the signal of controller to drive the air fuel injectors. You can see the schematic in appendix #1. With this method, we have the entirely control of the time and the duration of the air injection. Moreover, this electronic circuit is designed to activate the injectors faster than usually. This characteristic permits to keep performance of the engine in higher revolution.

KEEPING THE PERFORMANCES – To keep the eye on the track and give some challenge this year, the 2-stroke DI engine is the symbol of power and ecology. To achieve some pollution standards, we're going to use the new DI technology. This new stuff is applied on outboards engines. The tight rules of California forced the manufacturers to develop special features. The Nissan TLDI and the Bombardier Sea-Doo, both DI two-stroke engine, surpass the EPA and CARB(California Air Resources Board).

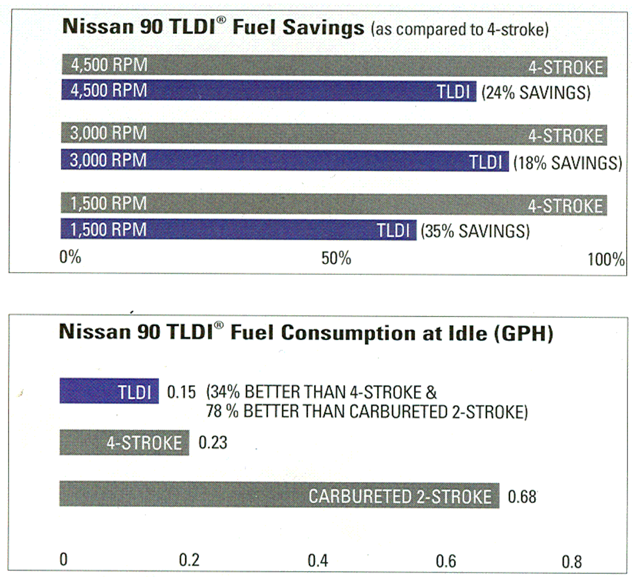


Figure 8: Comparison table of a Nissan TLDI and a standard 4-stroke engine.

But the injection is not the only thing to do to reach the best scores of the Clean Snowmobile Challenge. We worked on principal parts of them to achieve the higher standards. Exhaust, soundproofing, suspension and slides join together; make a new ecological sled.

TRANSMISSION – To keep the performance of our sled, we work on several small things. In this order the suspension modifications have some effects on the reliability and the effectiveness of the snowmobile. The strap and the pulley is a factor of quality in the choice of a good machine. Our new strap is design to get a better transmission rate and to avoid speed drop at high speed. The exact length eliminates the tension and the excessive friction. In other idea, the length tolerance minimizes slip and wearing of the system. So all of this factor give to the transmission a quickly reaction, a better grip and a lower clutch time. [10]

Obviously, we work on the clutch too. To be certain that the strap is going to grip at a lower rpm, we applied a new technology. The metal ball blasting is a new type of operation that we do on snowmobile's clutch. The goal is to spray at high speed metal balls on the clutch to change the quality of the surfaces. It makes a rougher surface to give a better grip at the strap.

TRACK AND SUSPENSION – There's a lot of other type of modification we can use to improve the quality of our snowmobile. Like you certainly know, the fabrication of the sprocket-wheel is not made one by one. When you take a batch of pieces for the assembly, you will certainly have different tolerances. It's why we decide to evaluate the alignment and the eccentricity. The analyzes demonstrated that the sprocket-wheel eccentricity is offset of 1/8 inches. So that told us that the forces was not transmitted correctly and the major part of them was giving by the chain case side. By machining the sprocket, we rebuild the eccentricity. That's going to adjust the force propagation on all the sprocket wheel and give to the track a better transmission movement. The wheels present on the tunnel have effects on the friction. We saw on the slides that the wheels gave to the tracks a wave movement. So at every time that the track pass a wheel, that gave shocks on the slide and it use prematurely. It directly connected to friction and the engine power. By measuring the groove presents on the slides, we find that the entire wheels diameter was 1/8 inches higher then the slides dimensions. So the machining of them gave a better contact of the track on the slides and reduces friction.

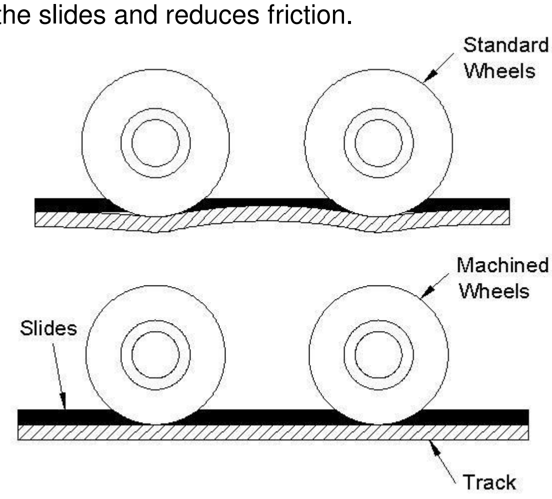


Figure 9: Friction caused on the slides due to the larger diameter of the wheels.

The wheels bearings could be change too. We saw that the quality of the bearings on our sled was not at the top that we can have. Because they were not sealed, we saw a lot of corrosion, so we change them for new sealed bearing. Finally, the friction quality of the bearings can be change too, to avoid friction and give to the wheels a better rolling movement. We change the NSK 6205DU5 for SKF 6205 2RSH.

To conclude our tunnel modifications, we install a Teflon sleeve in the plastic slides. Because we upgrade the contact of the track on the slides by machining wheels, we were obligated to reduce friction between them. We machine a groove in the plastic slide and insert a Teflon band in.

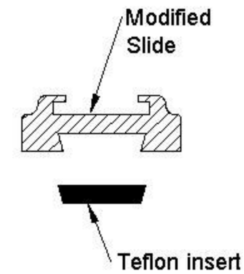


Figure 10: New slide design with Teflon insert.

We chose the Teflon UHMW because it's the materiel who offers the lowest friction coefficient with the steel. That type of technology is already using in high speed snowmobile competition.

MATERIAL 1	MATERIAL 2	Coef. Of Friction	
		DRY	Greasy
		Static	Sliding
Bronze	Steel		
Copper	Copper	1	
Glass	Glass	0,9 - 1,0	0,09-0,12
Graphite	Graphite	0,1	
Graphite	Steel	0,1	
Iron	Iron	1	
Nickel	Nickel	0,7-1,1	0,12
Nylon	Nylon	0,15 - 0,25	
Platinum	Platinum	1,2	
Plexiglas	Steel	0,4 - 0,5	
Polythene	Steel	0,2	
Silver	Silver	1,4	
Steel	Brass	0,35	
Steel	Cast Iron	0,4	
Steel	Graphite	0,1	
Steel	Zinc	0,5	-
Teflon	**Steel**	**0,04**	**0,04**
Teflon	Teflon	0,04	0,04

Table 2: Coefficient of friction table for different materials. [11]

So all those small modifications are going to reduce the gas consumption, pollutant emissions and add more power for the acceleration.

EXHAUST SYSTEM – For the exhaust modifications, we had some compromise to do between power and noise reduction. To keep the power of the engine, we have to avoid restrictions and keep fluidity of the exhaust gas. These criteria are the baseline for automotive design.

Last year, the first time we try our exhaust, we used a 1 ½ inches diameter. The data obtained on the dynamometer showed that the restriction was too high to develop good performance. So, we tried different diameters, and observe the impact on the power. With the new 2 ½ inches diameter pipe, we almost reached the power of the initial sled. In regard whit what we did last year, we focused our research in the same way. The principal sources of problem appeared after the tuned pipe. If we're not able to keep the flow, that's going to increase the pressure and obstructed the exhaust. This is the biggest reason that we divided the exhaust system. Another 2 inch pipe was add to the line. That's going to reduce restriction and increase the flow.

In the continuous way, we try to keep fluidity by minimizing the directions changes that gives losses to the system. We avoid 180 and 90 degree straight cuts to give smoothness to the exhaust.

EMISSIONS

FUEL FLOW IN A 2-STROKE ENGINES – Usually, the 2-stroke engine is considered as a dirty engine. The levels of pollutant emitted by this kind of engine are huge. It is mainly because the engine's fluid circulation is not very good. To avoid this problem, we concentrated our efforts on two solutions: the circulation of fuel and type of lubricating oil used. In the conventional 2-stroke engine, the air-fuel mix came in contact with lubricating oil and this oil was transported by this mix because of the detergent characteristic of fuel. This new mix did not help us with our emissions because a big part of this air-fuel-oil mix is not burned. Moreover, when this mix goes up in the combustion chamber, a part goes out directly by the exhaust port. The following diagram shows a 2-stroke engine working with a standard carburetor. We can clearly see the unburned gas going out the exhaust.

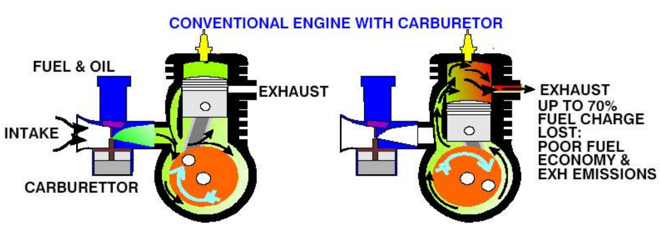


Figure 11: 2-stroke engine with carburetor system.

With the Synerject system, the fuel does not enter in the engine by the same path. It doesn't pass in the engine's base. This characteristic helps to keep a cleaner and better combustion. The air-fuel mix enters from the top of the combustion chamber and only when all ports are closed by the piston. This way, we make sure that we are always burning the right amount of air-fuel mix. The lubricating oil stays in the engine's base because only air circulates there. In consequence, the combustion does not burn any oil. The exhaust gases are evacuated only by air and we do not reject unburned fuel or oil. The next figure demonstrates how clean direct injection is on a 2-stroke engine.

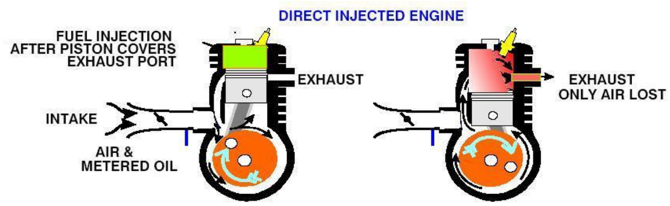


Figure 12: 2-stroke engine with direct injection system.

BLUE MARBLE LUBRIFICATION OIL – The lubrication of the engine plays a significant role in reducing the pollutant emissions of the engine. So, we decided to use an environmental oil called Blue Marble.

The Blue Marble oil is a superior mineral oil and it uses the new metal conversion technology. What it does is converts the metal surfaces, creating a new compound in the 25-55 angstroms thickness range. This new compound is thermally reflecting and less conductive then the starting metal. It seems like the function of the ceramic used to envelop pistons and domes. This compound is part of the actual metal surface and it acts in a same way graphite or Teflon work in plumbing.

Also, taking advantage of its thermally reflective qualities, most snowmobiles running Blue Marble have a hotter exhaust temp, so it burns cleaner in the piston chamber. This results in less unburned gas and lower emissions, so it burns better for the environment.

The converted surface also prevents the oxygen from reacting with the metals, making them rust and corrosion resistant. This property also aids in providing more oxygen in the combustion process as less is reacting with the metal surfaces during the heat and pressure of combustion.

Additionally, Blue Marble oil is biodegradable. It surpassed the U.S. Coast Guard's Bioassay Shrimp Kill tests as well and is the only engine lubricant to do so. Containing no aromatics, it leaves considerable fewer odors and virtually no trail smoke. [12]

NOISE REDUCTION

The noise produced by the snowmobiles is one of their major drawbacks. It can bother the people living near the trails and can be potentially harmful for the snowmobilers themselves. That is why the noise reduction is one of the main goals of the CSC. We can achieve this goal using many different methods. We have used two separate systems to ensure that our modified sled would be quieter than the original version. We fabricated a totally new exhaust system that as a good reduction of noise without restricting the exhaust gas and insulated the motor compartment with a new sound damping material.

The following table shows sound tests made on different sleds equipped with different exhausts. Those tests were made using SAE J192 standard for the Yellowstone National Park. The noise limit can not exceed 78 dB(A), but the National Park allows a 4 dB(A) grace to consider ever changing conditions.

Snowmobile models	Test 1 (dBA)	Test 2 (dBA)	Average
Arctic Cat 600 Powder			
SLP '99 Production Lightweight Silencer	81,6	83,7	*82,65*
SLP '99 Production Twin Pipes	82,4	84,2	*83,3*
Polaris 700 XC w/ 2-inch paddle track conversion:			
Stock exhaust	78,3	-	*78,3*
SLP '99 Production Single	81,1	81,1	*81,1*
SLP Prototype ERA 2000 Single Pipe	78,2	79,7	*78,95*
Polaris 600 XC:			
SLP '99 Production Single	79,3	-	*79,3*
Polaris 700 RMK:			
SLP '99 Production Twin Pipe	78,5	78,9	*78,7*
Yamaha 700 Mountain Max:			
SLP '99 Production Triple	84,5	83,2	*83,85*
SLP Triple Pipes with Prototype Silencer	76,1	76,1	*76,1*
	Total Average:		***80,25***

Table 3 : Noise measurements from 50 feet, for the Yellowstone National Park. [13]

As we can see, some of the sleds could not get in the park due to their high sound levels (higher than 81,9). We can also get our objective to beat an 80,25 dB(A) level at 50 feet with our combined modifications. Here are the first data we collected when we bought our sled, a 2003 MXZ Rev from Bombardier. All measurements are also made 50 feet away from the passing sled.

Sled Speed		**40 km/h**	**80 km/h**
Sound Level dB(A)	Test 1	75	84
	Test 2	75	85
	Average	*75*	*84,5*

Table 4 : Sound emissions from 50 feet of our stock snowmobile.

EXHAUST SYSTEM – We can see that the exhaust system of the snowmobile can help reduce the noise a lot. In our approach to keep maximum engine performance, we decided to use dissipative silencers. They create less pressure drop, which ensure a great exhaust gas flow. We have also perforated the inner pipe with holes varying in sizes and lengths. This helps silence various frequencies of noise. Our silencers are filled with ceramic fibers that absorb the sound waves when they come in contact with it. The following chart shows the decibel reduction in function of the frequency for a dissipative silencer. However, this chart does not take into account the variations in the hole patterns but is relatively accurate.

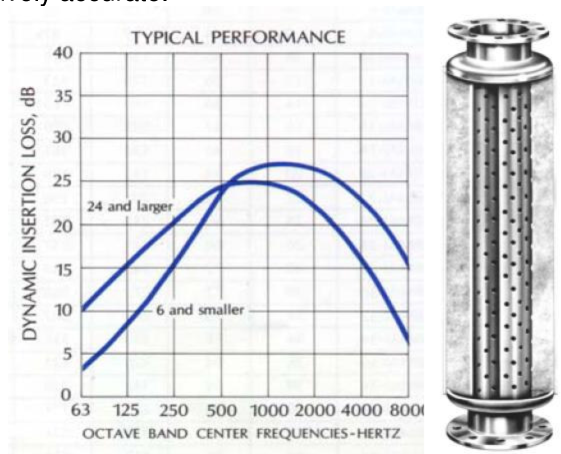


Figure 13: Sound reduction of a dissipative silencer. [14]

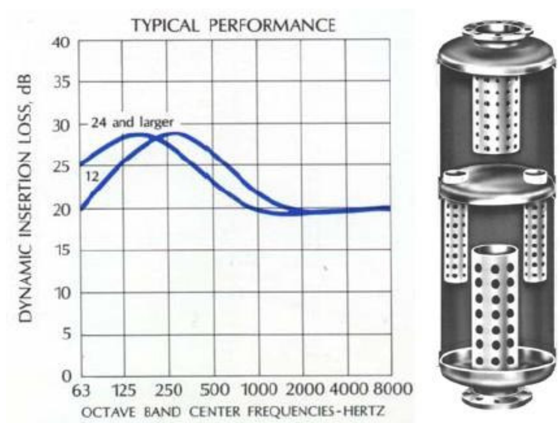


Figure 14: Sound reduction of a reactive silencer. [14]

We can also see that the reactive silencer is much more effective at our working frequencies. However, it creates a lot of pressure drop in the exhaust gas, which brings a loss of power and performance.

One of our team members worked for a company called Matech Technologie Inc. that does engine modifications for snowmobiles and motorcycles. He worked on a project to minimize space usage of the exhaust systems in snowmobiles. Instead of building a linear exhaust pipe, they made the exhaust come out from the middle section of the tuned pipe. This had various effects on the snowmobile. First of all, this had the effect of facilitating the exhaust flow while keeping the backpressure adequate in order to make the two-stroke engine work. This also made the tuned pipe less noisy. This is explained by a smaller pressure variation in the exhaust gas. At this point, it is important to know that a sound wave is a difference of pressure in the air.

In a standard tuned pipe, the pressure builds up in the two cone shapes located at beginning and the end of the pipe. In the mid section, the pressure drops due to the bigger volume of the pipe. When you connect the exhaust pipe in the mid section, the gas enters the system at a lower pressure. So the difference between the pressure at the end and at the beginning is lower, which creates less sound. The following sketch represents our new exhaust system design for our sled.

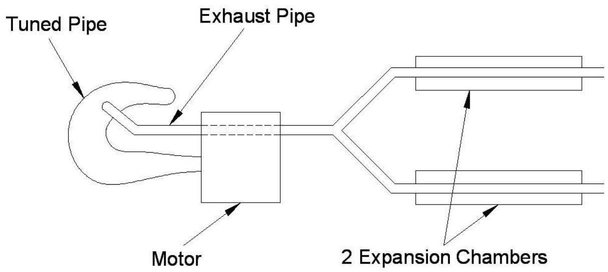


Figure 15: Basic schematic of our modified exhaust system.

Due to the lack of space of the Rev platform from Bombardier, we had to find a new way to build our system. Using the modified tuned pipe, we made the exhaust pipe pass under the motor compartment and then split the pipe in two to install our two dissipative expansion chambers under the two footboards. This way, we where able to maximize space usage and keep an aesthetic look.

SOUNDPROOFING – In addition to the sound coming from the exhaust system, a lot of noise comes from the motor itself, the different vibrations and the rotating parts, mainly the pulley and chain transmission. In order to reduce the sound emissions from the motor compartment, we have decided to insulate it completely.

Figure 16: Interior of the right hand side panel.

Sound absorbent – To start off, we closed all the openings on both side panels and around the chassis. We applied a sound-absorbing barrier inside all the panels surrounding the motor and under the hood. This material is made of two layers of polyurethane foam with different densities, joined together by a rubber section. The different densities of foam absorb a wider range of frequencies and help reduce the overall noise. The top foam is also covered with a thin sheet of aluminum to protect the material from heat radiation. It has also a self-adhesive back to facilitate installation.

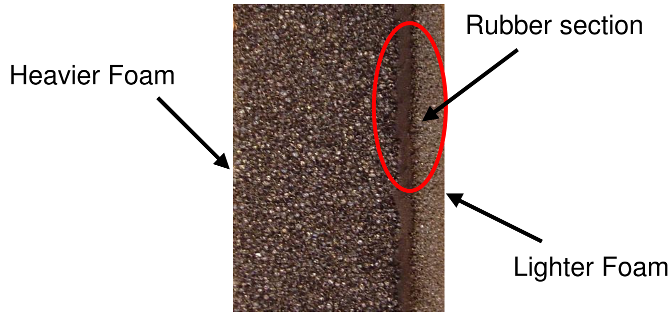


Figure 17: Cross-section of the sound absorber.

The following chart shows the effectiveness level of sound absorption in comparison with the frequency of the noise. In a snowmobile, the sound frequencies vary generally between 50 and 400 Hz. The foam absorber shows good efficiency in this range of frequencies but lacks stopping the lower frequency noises. With the addition of the rubber section, which adds mass to the barrier, we should get improved results at lower frequencies.

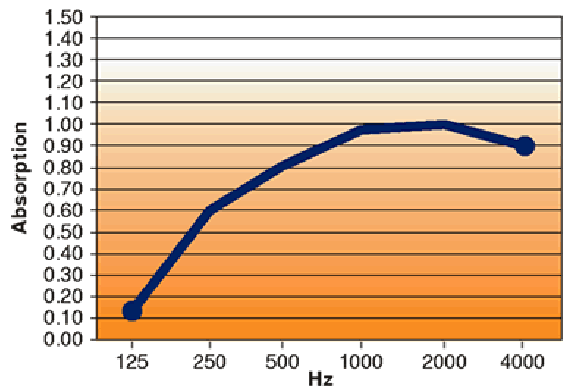


Figure 18 : Efficiency of noise absorption in comparison with the sound frequency. [15]

However, we could not install the sound absorber everywhere because it caused interference with some major component and we were not able close the panels. This was the case with the intake chamber and in the left side panel and the clutch cover. We have also added some foam in the intake box to further minimize the sound coming from the air intake.

Now that the cab is mostly closed and that there is not much air circulation, we could, have over-heating problems. For the motor, which is liquid-cooled, it's not that critical. On the other hand, it can cause problem on the electrical components. Also, the exhaust system could become very hot and damage our sound absorbing material where they are in direct contact. We needed some kind of ventilation.

Figure 19: Picture of last year's hood panel with the nostrils.

The “nostrils” – In order to ventilate the cab, we brought back the idea we came up with last year, the nostrils. Located at the front of the snowmobile, they force cold air in the cab while riding and keep the noise from coming out. This year, we fabricated a completely new fiberglass hood using the standard model with last year’s nostril for the basic mold. Also, the fiberglass used as good sound absorbing capacity. Combined with the sound barrier, we will get better results.

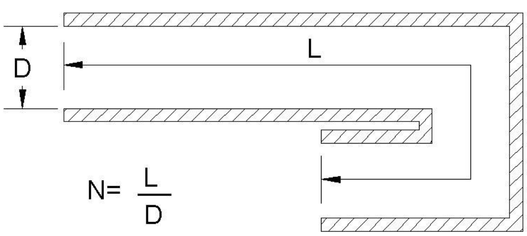


Figure 20: Schematic of the "nostrils". [16]

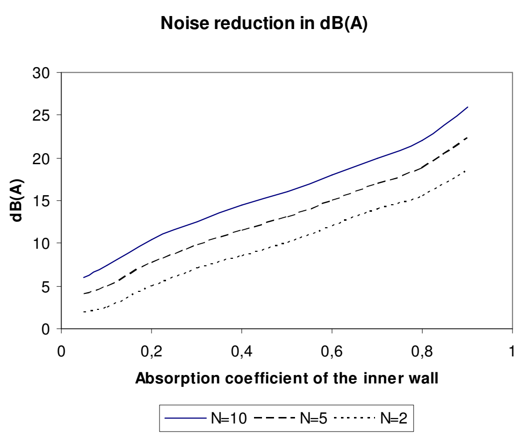


Figure 21: Noise reduction in function of the nostril's design. [16]

Because the nostrils created holes in our insulated cab, we needed to make sure the noise would not come out or reduce the amount of noise coming out. To achieve this, we used flexible aluminum tubing to create air ducks. They are shaped in a “U” to create a tight turn in which the sound could come out, but with far less intensity. Because the air will be forced in, this will also help reduce the noise.

After installing the ducks, we applied our sound absorbing material under the hood to cover the ducks, which completed the insulation.

Finishing touches – To finalize the soundproofing, we used self-adhesive rubber strips to seal the junctions between the different panels. This way, we minimize the sound leaks where we have gaps and improve our sound insulation.

COST

The overall cost modification of our sled is low because all our modifications are all easy to manufacture or are made with standard pieces and equipments. The following table shows the different modifications we did with the different price values. These values are taken directly from the technology implementation cost assessment sheet of the CSC 2005. We are also able to keep a low modification cost because we did not a use a lot of complex electronic systems and electrical drives.

Modifications	*Value*
Fuel System	
Fuel Pump	26,00 $
Fuel System	105,00 $
Direct injection system	450,00 $
Throttle Body	25,00 $
Exhaust	
2 Silencers	80,00 $
Electronics/Control	
Battery	41,00 $
Engine management system	125,00 $
Noise Treatment	
Insulation	32,50 $
Total cost of modifiactions	***884,50 $***

Table 5: Total cost for modifying our sled.

CONCLUSION

With this year’s design, we believe that the different systems used on our sled are the way to progress with the two-stroke engine technology. Working with an electronic direct fuel injection, improved exhaust systems and making a good sound insulation, we were able to reach all the major requirements to have a truly clean snowmobile. Although we made major changes on the motor and the look of the snowmobile, we kept good performances and an edgy design that appeal to the snowmobilers. We already await next year’s competition in order to develop new and advanced systems.

ACKNOWLEDGMENTS

We would like to thank everyone who helped us bring this project to reality; The “Ecole de Technologie

Superieure", the Students Association and all of our sponsors for their financial support; Matech Technologie Inc., Trans-F-Air and A.Malo for their technical assistance and their generous gifts. You helped us prove that the snowmobile industry can be clean and environmentally friendly.

We would also like to thanks the Clean Snowmobile Challenge organization and Michigan Tech for hosting the event and bringing all the teams together to find new and innovative solutions to boost the overall image and reputation of snowmobiling.

REFERENCES

1. J. Armand Bombardier Museum
http://www.fjab.qc.ca/entrance.htm

2. International snowmobile manufacturers association
http://www.snowmobile.org/stats_units_canada.asp

3. Zins Beauchesne and Associated Evaluations of the direct economic impacts of the tourism practice of the snowmobile in Quebec in 2000-2001, January 2002.

4. Radio-Canada
http://radio-canada.ca/regions/Montreal/nouvelles/200412/02/004-JUGEMENTMOTONEIGE.shtml

5. United States Environmental Protection Agency, September 2002
www.epa.gov/otaj/regs/nonroad/2002/f02040.pdf

6. Canadian council of snowmobile organizations
http://www.ccso-ccom.ca/newsite/fsnowinfo2.html

7. Motoneige.ca
http://www.motoneiges.ca/actions/mainMenuClick?item=main&page=articleDetails&id=231

8. Econologie.com
http://www.econologie.com/articles.php?lng=&pg=717

9. Synerject web site
http://www.synerject.com/modules2.html

10. Kimpex, recreational vehicles accessories dealer
http://www.kimpex.com

11. Coefficient of friction table
http://www.roymech.co.uk/Useful_Tables/Tribology/co_of_frict.htm#coef

12. Blue Marble Canada
http://www.bluemarblecanada.com

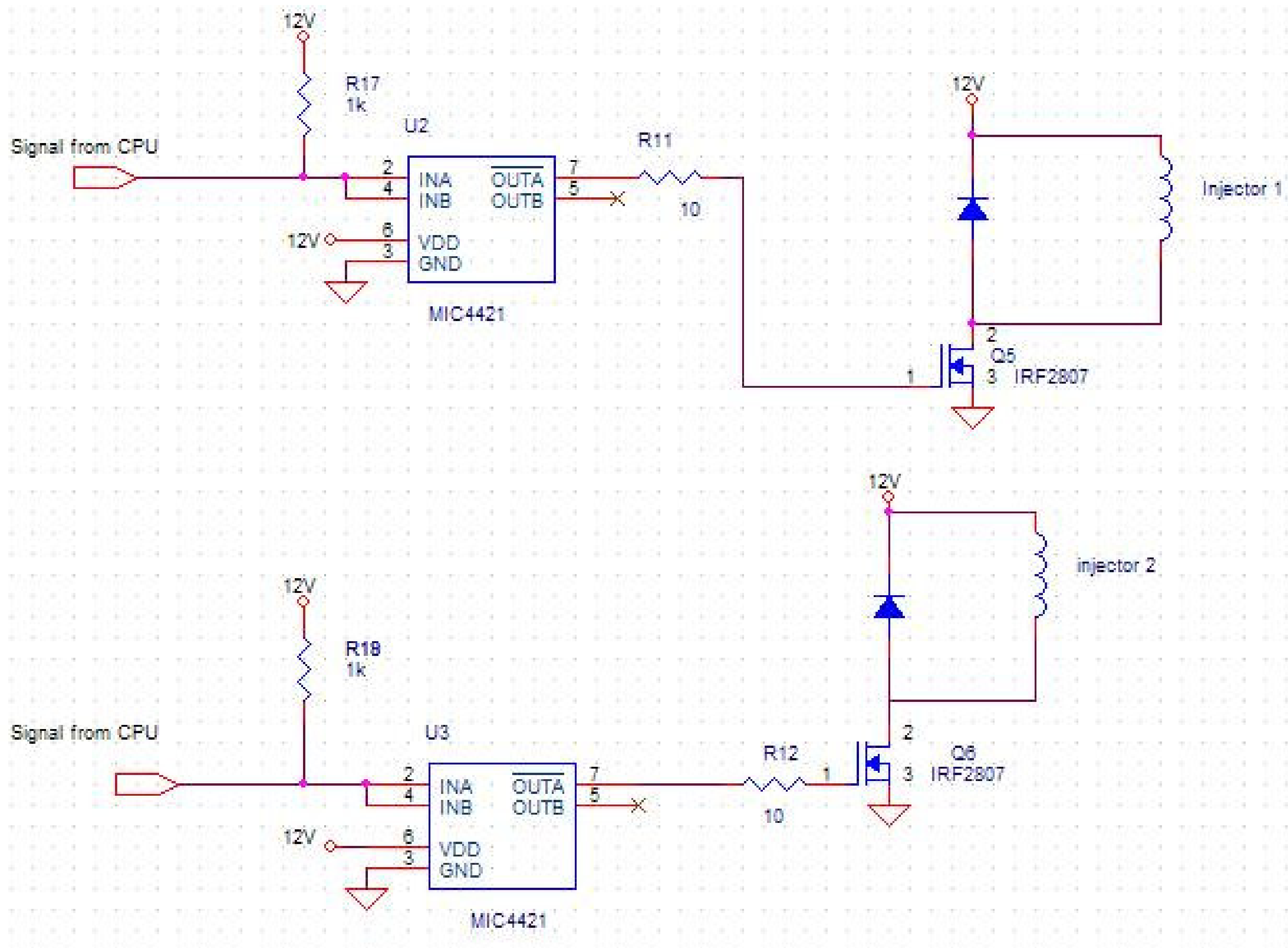
13. MATHWES, J. of Starting Line Products, "What is noise? Is snowmobiling being silenced?", February 7, 2002.
http://www.off-road.com/snowmobile/info/sound/whatisnoise.htm

14. EVANS, Jack B. of JEAcoustics, "Engine test cell noise emission design with performance validation results", England, September 2002
http://www.jeacoustics.com/library/pdf/JLFevans.pdf

15. Acoustical Surfaces Inc.
http://www.acousticalsurfaces.com

16. LAVILLE, Frederic, School documentation for the acoustical engineering course. Revised August 2001.

APPENDIX #1


12V
R17
1k
U2
Signal from CPU
2
4
INA
INB
$\overline{OUTA}$
OUTB
7
5
R11
10
12V
6
3
VDD
GND
MIC4421
12V
Injector 1
2
Q5
1
3
IRF2807
12V
injector 2
12V
R18
1k
Signal from CPU
U3
2
4
INA
INB
$\overline{OUTA}$
OUTB
7
5
R12
10
1
2
Q6
3
IRF2807
12V
6
3
VDD
GND
MIC4421