SUNY University at Buffalo

The UB Approach to a Diesel Powered Snowmobile

Chris Battaglia, Steve Battaglia, Jake Ennis, Kevin Gastle
William Goodfellow, Eric Peckham, John Williams
Team members – SUNY Buffalo Clean Snowmobile Team

ABSTRACT

The ever increasing concern over the environmental impact of snowmobiles on the surrounding environment has been discussed by those in government to those participating in the sport. Due to the increasing popularity of snowmobiling, snowmobile manufacturers have had to rethink their design. Today's manufacturers are producing snowmobiles that are more environmentally friendly and still acceptable by those who participate in the sport. One solution is a diesel engine implemented into a stock snowmobile chassis. The SUNY University at Buffalo (UB) Clean Snowmobile Challenge (CSC) design utilizes a Daihatsu three cylinder diesel engine in a Polaris Pro-X chassis. The implementation of the diesel engine, along with an exhaust after treatment system, can be a viable solution to the Clean Snowmobile Challenge. Implementing these designs into a stock chassis results in a snowmobile that is environmentally friendly and still fun to ride and drive.

INTRODUCTION

Due to the increasing regulations on exhaust and noise emissions on modern snowmobiles, there is an ever-growing need for further development of new technologies that assist in making snowmobiles cleaner and quieter. The Clean Snowmobile Challenge is a collegiate design competition for student members of the Society of Automotive Engineers (SAE). "The intent of the competition is to develop a snowmobile that is acceptable for use in environmentally sensitive areas. The modified snowmobiles are expected to be quiet, emit significantly less unburned hydrocarbons, carbon monoxide and particulate matter than conventional snowmobiles, without significantly increasing oxides of nitrogen emissions. The modified snowmobiles are also expected to be cost effective. The intent of the competition is to design a touring snowmobile that will primarily be ridden on groomed snowmobile trails. The use of unreliable and expensive solutions is strongly discouraged" [1]. Guidelines for the 2007 SAE Clean Snowmobile Competition state that this years entries into the competition must surpass the 2012 emissions standards just as the manufacturers must do. Additionally, entries must pass the current Snowmobile Industry noise test minus two decibels.

PROBLEMS WITH TODAY'S SNOWMOBILES

The predominant use of hydrogen and carbon based fuels in snowmobiles leads to hazardous emissions from the combustion process. Hydrocarbon (HC), carbon monoxide (CO), and nitrogen oxides (NO_x) are the most harmful of the exhaust molecules and must be minimized. In order to create a solution to the emissions problem, the cause of the formation of the particles must first be understood.

Un-burnt hydrocarbons can be a result of: incomplete combustion, flame quenching, crevice volume, absorption of fuel vapor, or high equivalence ratio. Incomplete combustion normally occurs during the expansion stroke, when the cylinder pressure drops, causing the unburned gas temperature to drop. This temperature drop causes a decrease in the burn rate. Flame quenching can be attributed to the relatively cold walls of the cylinder. The cooler walls form a boundary layer where the flame cannot penetrate, hence leaving some unburned HC molecules. Crevice volumes, such as the area between the piston and cylinder wall, can once again trap hydrocarbons in a region where the flame cannot enter. The mode of absorption of fuel vapor into the thin oil layer occurs during the compression stroke. Once the pressure gets to a certain level, the fuel vapor can be absorbed into the oil layer. Upon expansion, the fuel vapors containing unburned HC are emitted from the oil layer and exit out through the exhaust. Hydrocarbons are also known to be sensitive to the equivalence ratio, ϕ. When ϕ is greater than one, the fuel is rich and consequently HC emissions are high. Conversely, when ϕ is less than one the fuel is lean and the HC emissions drop down.

Carbon monoxide formation is mainly a function of the equivalence ratio. Similar to hydrocarbon formation, CO emissions will increase with a rich fuel mixture, and decrease with a lean fuel mixture [2]. The CO is formed when there is not enough oxygen present to form CO_2. Therefore, poor mixing and incomplete combustion also play a factor in increasing CO emissions [2]. Normally, CO emissions range from 0.2% to 5% in the exhaust of a spark ignition engine [4].

The formation of oxides of nitrogen are caused mostly by high temperatures and large oxygen concentrations in the combustion chamber. The high temperatures cause the nitrogen to dissociate, and NO/NO_2 forms if there is oxygen present [3]. Equivalence ratio affects both oxygen content and temperature. Maximum temperature occurs at an equivalence ratio of 1.1, but oxygen concentration decreases as equivalence ratio rises, and is too low at ϕ=1.1. The maximum amount of NOx emissions has been empirically found to be at approximately ϕ=0.9 [2].

The new emissions problem faced by our team for the 2007 CSC is particulate matter (PM). PM is created by the incomplete combustion of diesel fuel combined with high sulfur content in the fuel. In the last year the United States has come a long way in diesel emissions technology. New Environmental Protection Agency laws have been passed to decrease diesel engine emissions. The creation of Ultra-Low Sulfur Diesel (ULSD) and mandating the use of ULSD has also helped to advance emissions technology. The new 2007 standards set by the EPA for diesel engines has created havoc in the diesel engine design, thus increasing the advancement of exhaust treatments and active emissions systems. All of these advancements have led the way to the UB CSC team using diesel in 2007.

UB SOLUTION

For the 2007 CSC the UB team has decided to step outside the box and power the snowmobile with a three cylinder diesel engine. Due to the recent advances in diesel performance and exhaust treatment, the diesel engine can be considered a clean and quiet engine. The other goal for this year is to set up a snowmobile which can built and developed over the next few years to create a team timeline, where project sleds are used for two or more years. The 2007 goal concentrations are as follows:

- Implementation of a Diesel Engine
- Reduce Engine Emissions
- Reduce Engine Noise
- Maintain Performance
- Increase Reliability
- Improve Fuel Economy
- Rider Safety and Comfort

PERFORMANCE

ENGINE OPTIONS

Selecting a motor for the CSC is one of the most important aspects in the design of an environmentally conscious snowmobile. First, the engine must be within specifications set forward by competition rules. This consists of engine types and displacement sizes. We must choose from the selection of rotary, two-stroke, four-stroke gasoline engines or diesel engines. The displacement of these engines is mandated with maximum limits. With these options in mind, the team must pick an engine which is suitable for designing an innovative snowmobile to revolutionize the snowmobiles of the future.

The UB CSC team has wanted to do a diesel powered snowmobile for some time. With the recent technological advances in exhaust treatment we are now able to implement a diesel engine into the 2007 CSC. After deciding on a diesel power plant we had to concern our selves with size, weight, power, and availability.

ENGINE SELECTION

The 2007 UB CSC team looked at several diesel engines with a displacement size that would adhere to the rules. The end decision was to go with a Briggs and Stratton, Vanguard three cylinder diesel manufactured by Daihatsu. The engine is a 952 cubic centimeter (cc) inline three cylinder direct injected four stroke diesel engine. This engine is implemented in commercial lawn mowers and personnel lifts. Knowing that the motor is implemented in commercial lawn mowers and debuting in the 2007 6x6 Argo vehicles gives credibility to the durability of the engine.

The diesel is a 32 horsepower turbo charged engine with 58 ft-lb of torque. The lower engine output creates a power shortage compared to current snowmobiles but as discussed before this sled is only in the implementation stage. Due to the new technology available there is a lot more that can be done to improve the power of the engine. The engine is relatively small and fits in the bulk head of the chassis with a half inch to spare on either side. Figure 1 shows the Daihatsu engine’s dimensions complete with a fan for the radiator, which was not utilized in our design. To maintain the engine temperature inside of an enclosed hood we utilized the stock snowmobile heat exchangers located under the tunnel.

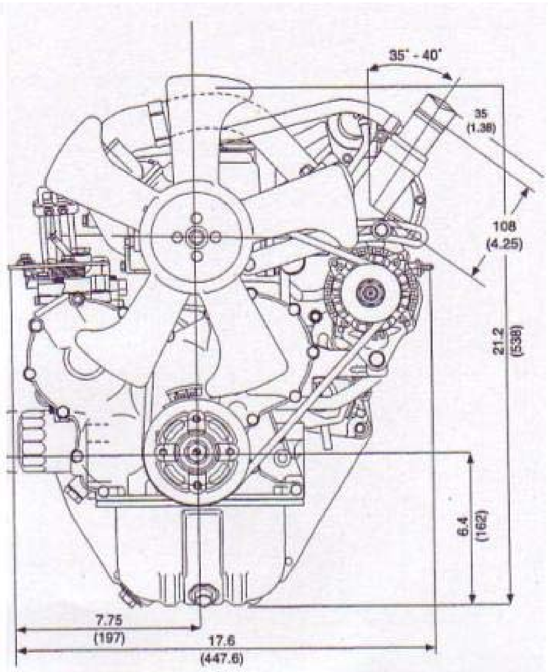


Figure 1: Daihatsu Diesel Engine

The diesel is able to be mounted in a variety of different positions, provided by the 15 degree running angle and 25 degree intermittent running angle. The ability to mount the engine in a variety of different positions gives us the ability to utilize the limited space in the chassis and create a more central center of gravity. Due to the diesel's low center of gravity and the angle of mounting we were able to keep the sleds center of gravity as low as possible.

One of the major factors in running a diesel engine in any vehicle is that diesels are 30-40 percent more efficient than other internal combustion engines. Keeping this in mind our team is hoping for drastically increased fuel economy over two and four stroke snowmobiles. The only real set back to using a diesel engine is the emission of particulate matter (PM).

FUEL SYSTEM

The fuel system on the Daihatsu diesel is relatively simple because it is mechanically injected. The four parts to the fuel system are the injector pump, fuel filter/water separator, injectors, and the fuel tank; all of which are connected via fuel lines. Due to the injector pump's ability to pick fuel up from fifteen inches below its inlet a feeder pump was not necessary. Some unique features to the Daihatsu engine are the steel fuel lines that supply the injectors after the injector pump, and the fuel filter/water separator which has a built in water level warning light and fuel priming pump for when the system is run dry. Since diesels are much more efficient than two and four stroke engines we decided to reuse a redesigned fuel tank that holds only 6.5 gallons of fuel, which makes the tank lighter and the overall sled lighter. Reference Appendix A for a fuel system diagram.

INTAKE DESIGN

. Considerations for the intake design included: optimization of the limited space available for the air box, obtaining the coldest, densest air possible from the surroundings, minimization of the pressure losses through the charge tube and intercooler, resonance tuning to maximize the intake pressure, and creating an easily removable, esthetically pleasing intake system. Due to the use of a stock RHF3 turbocharger incorporated into the Briggs & Stratton engine, a liquid cooled intercooler must be incorporated into the air intake system.

The stock turbocharger inlet orientation dictated the placement of the air box to be adjacent to the brake rotor. A forward facing intake design was chosen to increase backpressure to the turbocharger, reducing pressure lag during the spooling phase, and also to obtain the coldest air possible. The intake channels from the hood run into the air box. The entrance port of the air box is lined with large cell foam. This foam helps to prevent any water or snow from entering the intake system, with no adverse effects on the air flow due to the extremely large cell size. The air box is incorporated within the hood design to reduce vibration noise produced between the box and hood during testing.

In order to reduce pressure loss through the intake system two major design variables had to be addressed. First, the longer the total tube length of the system the greater the overall pressure loss will be. To solve this problem the total distance the air must travel from air box to intake manifold is <24 inches. Second we tried to eliminate any sharp turns in the intake. In order to facilitate laminar air flow through the system no tube angle was to exceed 45 degrees. These factors in combination with the use of mandrel bent tubing helped to significantly reduce the pressure loss through the intake system.

The total pressure loss through the intake system was calculated by using flow through tube equations and by modeling the intercooler as a tube bank. After calculating the pressure loss through the intake charge tube and intercooler portions of the intake the total loss in pressure was estimated to be .5psi.

Intercooler

The type of intercooler that would be optimal for the new design is a water to air intercooler, for the following reasons:

- Small and compact
- Location or mounting position
- Allows sealed hood design to reduce noise
- Allows for a more constant intake temperature

The biggest disadvantage to this type of intercooler is the added weight from an additional coolant system.

The intercooler was designed to decrease pressure losses by having an orientation that eliminates the 180 degree bend in the charge tube from the turbo. The air enters the intercooler at an angle of 90 degrees to the flow path through the intercooler and is smoothly expanded into the fins. The exit of the intercooler is the opposite of the entrance with the directed flow being 90 degrees again from the exit of the core of the intercooler. This completes the 180 degree bend necessary for air delivery to the engine. Theoretically, by using the intercooler as a type of expansion chamber, it slows the flow down, and associated pressure losses are less when changing flow directions with smaller flow rates. The geometry of the intercooler that fits within our spatial limits can be viewed in the figures below:

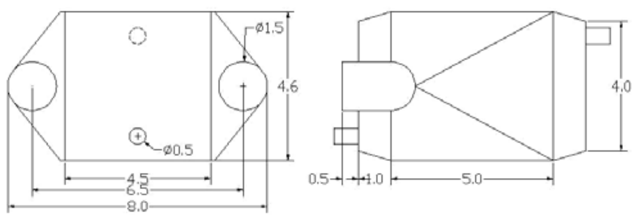


Figure 2: Intercooler Geometry

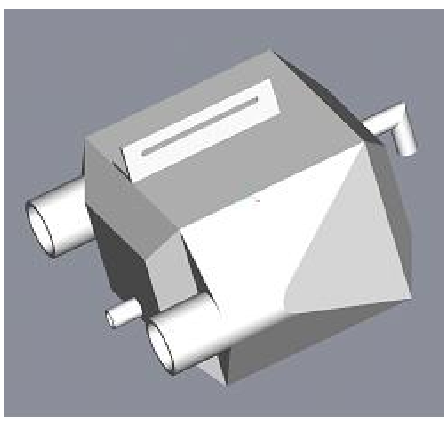


Figure 3: Intercooler Model

Diesel engines tend to run better with slightly warmer intake air than gasoline engines. The projected goal for engine intake temperature was a constant 30 degrees Celsius. The intercooler has potential for cooling at a heat transfer rate of 74.6 kW. The temperature at the exit of the turbocharger under full loads ranges between 45 and 110 degrees Celsius. This correlates to a necessary heat transfer rate of 55.7 kW to keep the intake temperature at 30 degrees Celsius.

Therefore, the intercooler will not be the limiting factor when trying to cool the intake temperatures.

The new design problem that surfaces is sizing the snow to air heat exchanger that cools the coolant from the intercooler. First the convection heat transfer coefficient is calculated. This is done starting with equation (1) [4] seen below. For this specific situation we have a laminar flow within the heat exchanger. This is determined from the small Reynolds number computed using equation (2) [4]. The use of a hydraulic diameter is required in these calculations due to the rectangular shape of the coolant flow cavity within the exchanger. Since the exchanger is not infinite in length Le, it is assumed that there are entry region affects. Since the flow is laminar and there are entry affects, the Nusselt number is computed from equation (3) [4]. From here the average convection heat transfer coefficient, hi, is calculated using equation (4) [4]. From here, equation (1) is solved for the surface area [4]. Finally, the length of the heat exchanger Le can be solved for, given a desired heat transfer rate q. Equations are shown below:

1. $q = hi\ As\ LMTD$ [2]

$$As = \frac{q}{\mathrm{hi}(LMTD)}$$

$$Le = \frac{As}{\mathrm{N}(2h + w + s)}$$

hi = internal convection coefficient
As = surface area
Le = Overall length of heat exchanger
N = Number of fins
h = height of fin
w = thickness of fin
s = fin spacing width

2. $$Red = \frac{\rho\ V\ Dh}{\mu}$$ [2]

3. $$Nud = 1.86\left(\frac{Red\ Pr}{\frac{L}{\mathrm{D}}}\right)^{\left(\frac{1}{3}\right)}\left(\frac{\mu}{\mu\ s}\right)^{.14}$$ [2]

4. $$Nud = \frac{hi\ Dh}{k}$$ [2]

k = thermal conductivity

The results from the calculations above reveal that the intercooler needs to be 34.5 inches in length with 0.375 inch fins to achieve a heat transfer rate of 55.7 kW.

Because our team has incorporated studs into our 2007 snowmobile design the availability for heat exchanger placement was greatly reduced due to stud travel. However it was discovered that there is enough clearance between the stock engine heat exchangers and the tunnel sidewalls to attach another set of stock heat exchangers. This addition provides well beyond the necessary 55.7kW heat transfer rate which can be controlled with the inline water pump. This increases the efficiency of the intercooler because it is an independent coolant loop that is not adversely affected by the engine coolant temperature.

ELECTRICAL SYSTEM

The main power distribution circuit is powered by a 12 V battery and supplies power to the starter, chassis harness, and engine wiring harness. The battery will be located next to the chain case on the right side of the snowmobile. This location was chosen because it is close to the components in need of its power, and also helps even out the side-to-side weight distribution. A plastic sealed battery box made from Lexan was built to provide a sturdy, nonconductive and hazard-containing container. Monitoring of the engine's vitals will be performed by an EGT system. This system will monitor intake temperature, intake pressure, coolant temperature and exhaust temperature. Reference Appendix B for the wiring diagram.

ENGINE MOUNTS

New engine mounts had to be designed and manufactured to implement the Briggs & Stratton diesel engine into the Polaris Pro-X chassis bulkhead. Due to the significant weight of the engine the mounts were designed to be in compression under the load of the engine. The lateral stiffness of the mounts had to be robust enough to not deflect when the clutch engages, but also isolate the engine vibrations. The Briggs & Stratton engine has a counterbalanced crank shaft and flywheel which allows for use of stiffer engine mounts to isolate vibration.

After contacting Briggs & Stratton engineers it was determined that the engine can be run at up to 15 degrees rearward tilt over long durations without adversely affecting the power output of the engine. Taking this into account the engine mounts were designed to allow a 10 degree rearward tilt to keep the engine's center of mass as low as possible in the chassis and minimize the hood modifications, due to engine height. Several current commercial applications utilizing this engine were evaluated to design the optimal engine mount. Taking these factors into account along with the stock engine mount locations the front and rear engine mounts were designed.

Front Mount:

The front engine mount is designed to attach the front left and right stock engine mounts to the shock tower cross member located in the front of the bulkhead. The U-channel base eliminates off axis engine torsion. The mount is manufactured from .25 inch 6061 aluminum plate, and is the most rigid of the three engine mounts.

Figure 4: Front Engine Mount

Rear Mount:

The rear of the engine is supported by two mounts, supporting opposite sides of the engine. The first mount is located on the serpentine belt side of the engine and is configured in an "S" shape. This design was chosen to avoid interference with the steering column and utilize the stock engine mount holes on the Pro-X chassis. Both rear mounts are manufactured from .25 inch 6061 aluminum plate. The second mount is located on the flywheel side of the engine and connects the upper bulkhead to the stock engine mount plate.

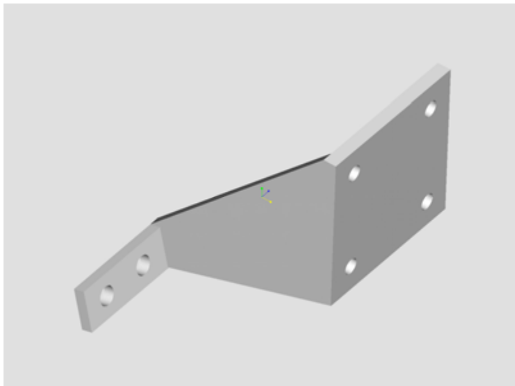


Figure 5: Rear Engine Mount (Serpentine Belt)

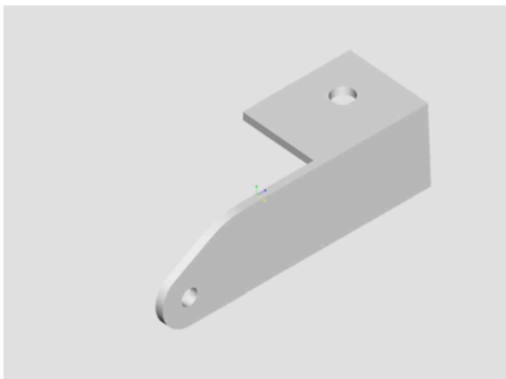


Figure 6: Rear Engine Mount (Flywheel)

CLUTCH ADAPTER

The Briggs & Stratton engine conventionally used a direct drive system to operate a hydraulic pump. In our application an adaptor had to be manufactured that would mount to the flywheel and turn down to the 6 degree taper necessary to receive the Polaris snowmobile constantly variable transmission. Since this part does not currently exist in the market it had to be custom manufactured by our team. A Pro/Engineer model of the clutch adapter is shown below:

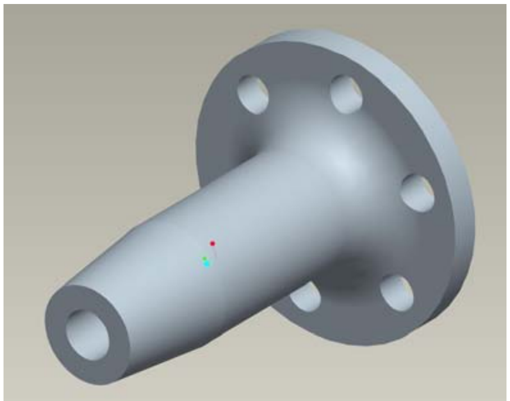


Figure 7: Clutch Adapter

The flywheel is attached to the engine crank shaft by 6 bolts arranged in a hexagon pattern. The adapter is designed such that the flywheel bolts can be removed and replaced with longer bolts passing through the clutch adapter and flywheel. It is necessary to leave the flywheel attached to the engine because it is a crucial member of the engine counterbalance.

The clutch end of the shaft has a tapped hole in the end to receive the stock Polaris clutch bolt which fastens the clutch primary to the engine crank shaft. The adapter is manufactured out of 1020 cold rolled steel for ease of manufacture, reduced cost and to avoid bimetal corrosion between the steel insert of the clutch primary and adapter. The major dimensions of the clutch adapter are shown in the figure below:

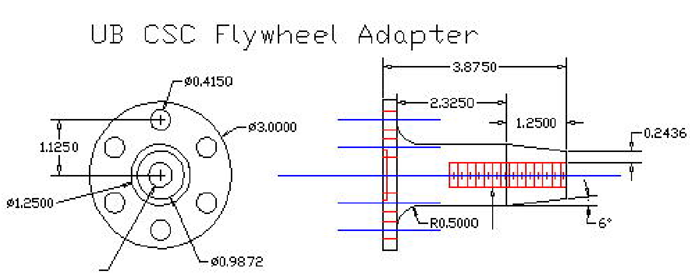


Figure 8: Clutch Adapter Drawing

Due to the minimal size of the clutch adapter and material selection our team felt it was necessary to perform finite element analysis on the part to ensure its durability. The ANSYS Finite Element Analysis program was used to determine the peak stress concentrations and total deformation under maximum torque situations. The test was designed to simulate full engine load of 60ft-lbs torque (on the bolts) with the clutch end of the shaft remaining stationary. A stress plot of the results is shown below:

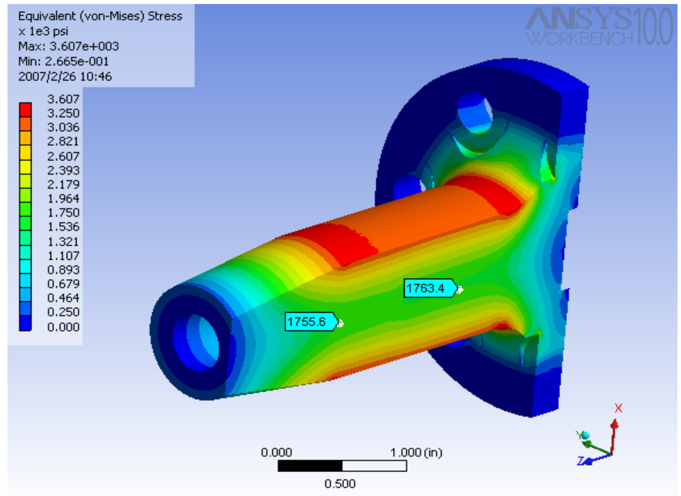


Figure 9: Clutch Adapter FEA

As identified by the FEA results above the clutch adapter as designed is capable of withstanding the maximum torque loads capable by the engine. The maximum equivalent (von-Mises) stress experienced by the shaft is 3,607psi, well below the yield stress of 1020 steel which is 35,000psi conservatively. Also from analysis, the total deformation of the adapter shaft under full load is .0004 inches. These two facts along with the shear stress analysis results provide evidence that the expected life of the shaft will long exceed the expected life of the snowmobile application.

CHASSIS SELECTION

The chassis that the CSC team is using for the 2007 competition is a 2003 Pro-X chassis that was used in the 2003 and 2004 competition. The original use of the chassis was for racing mogul racing circuits, where in the sleds would go over very large mogul bumps at high rates of speed. Knowing this information we can determine that this chassis will be able to handle our competition goals without breaking down. Since the chassis is built for racing it is also optimized for weight conservation and is one of the lightest chassis produced in 2003. Therefore it is a good chassis to use, as weight is being judged in the 2007 CSC. This chassis also allows for many adjustments in both ride quality and handling, which makes it an ideal chassis for this competition because we can fine tune the sled to perform to our needs.

SUSPENSION

The front suspension used this year will be a pair of FOX FLOAT Airshox. They eliminate the need for standard shock springs by using an internal floating piston coupled with high-pressure nitrogen gas. There is also a weight savings of about 6 lbs. due to the lack of an external spring. FLOAT Airshox also have a great amount of adjustability via a miniature air pump that changes the internal pressure of the shock. This allows for adjustability from race to trail conditions as well as rider weight in a matter of minutes. The rear suspension is from a 2003 Polaris Pro-X 440 race snowmobile. This suspension utilizes a pair of Walker Evans Racing shocks with remote reservoirs. These shocks also offer easy adjustability for different conditions and rider weights. The shock bodies are made of lightweight anodized aluminum and contain specially stabilized synthetic shock oil for consistent operation, even in extreme cold weather. The frame of the suspension is a heavy duty version of the Polaris EDGE suspension. This suspension allows for a ride that can handle deep bumps without easily bottoming out [6].

SKIS

A pair of C&A Pro XT skis have been implemented in our design. These composite skis are lightweight and offer a great amount of durability and prolonged wear. The aggressive design on the bottom of the ski allows for reduced darting and improved cornering. This design also diverts snow spray away from the rider which allows for improved visibility [7].

EXHAUST SYSTEM

Emissions

The exhaust system is designed to be an integral part of noise and combustion emission control. The exhaust system is designed to assist the snowmobile in meeting the 2012 EPA emissions standards. Diesel engines are substantial emitters of particulate matter and nitrogen oxides (NO_x), but only small emitters of carbon monoxide (CO) and volatile organic compounds (VOCs). Gasoline engines are the greatest emitters of CO and substantial emitters of VOCs and NO_x, but only modest emitters of particulate matter (PM). In order to decrease the amount of NO_x, CO, VOCs and PM we implemented an oxidizing catalyst, PM-filter, de-oxidizing catalyst (DOC) hybrid into our exhaust system.

Catalyst/PM-Filter DOC Hybrid

The main criteria for catalyst selection were combining the PM filter and Catalyst in one package and the minimization of exhaust backpressure. The Catalyst/PM-Filter DOC Hybrid works by first oxidizing the CO and HC. The next step in the process is the oxidation of Nitric Oxide (NO) into Nitrogen Oxide (NO_2). After the NO is split apart the PM-Filter uses the NO_2 to react with the PM to continually reduce it; the filter also traps the PM in a fleece where it is actively burnt at 200^{o}C. Figure 10 shows roughly how our system works [5].

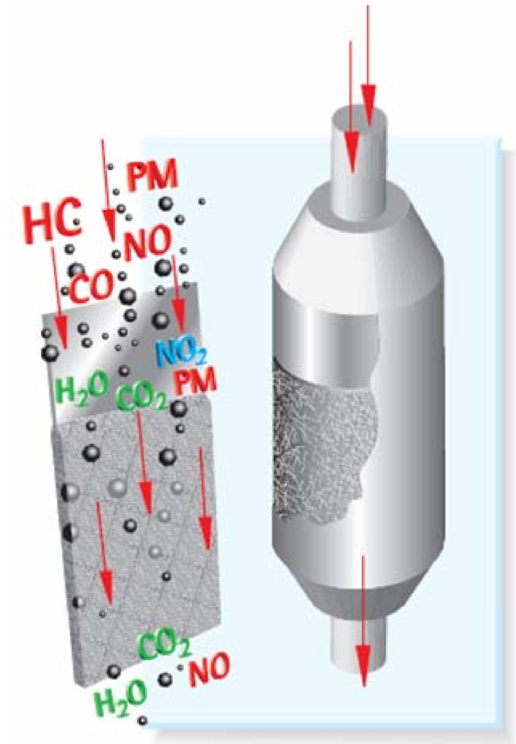


Figure 10: Catalyst/PM-Filter DOC Hybrid

Muffler

The main criteria for muffler selection were size constraint, noise attenuation, and the minimization of backpressure. The Aero Exhaust 194 Stealth was selected because it fits all of those criteria. The 194 Stealth is constructed of 304 stainless steel for corrosion resistance. There is an internal continuous perforated pipe that exposes the exhaust to a high temperature ceramic sound absorbent material. The high temperature ceramic sound absorbent material is rated up to 3000ºF, which makes it more durable (resistant to breakdown) than fiberglass.

Specifications

Part: S194

Weight: 7.5 lbs

Material: 304 Stainless Steel

Finish: Bright Polished

Body: 14"x9"x4"

OAL: 20"

I/O: 2" Single x 2" Single

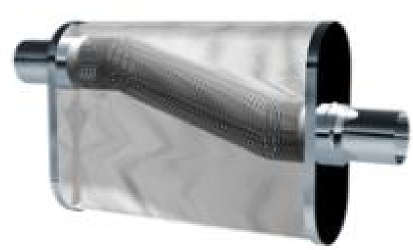


Figure 11: 194 Stealth Muffler

NOISE

HOOD DESIGN

A new hood was necessary because the stock Polaris hood proved to be inadequate in a few areas. The change from a two-stroke engine to a Diesel meant a significant change in necessary clearances, so this issue had to be addressed. Also, the stock hood did not provide adequate noise reduction; this can be attributed to the thin plastic material and multiple hood vents. The new hood was designed to provide adequate space for the new engine and to keep weight and noise to a minimum.

To create this new hood a plug had to be made to create a fiberglass rendition of our design. The top of the stock hood was removed, leaving only the base and gauge pod. A wire frame was then constructed according to the necessary clearances. The wire frame was then reinforced and strips of fiberglass matting were laid over it, this combination provided the shell of the new hood. On the right side of the hood, a forward-facing intake port had to be constructed. This port was constructed with a wire frame and fiberglass matting in the same manner as the top of the hood. These fiberglass sections were then smoothed out with body filler to create a nice finish. The outline of the new hood, also known as a plug, was then sent to a fiberglass shop to have a mold made.

The new hood was then made from this mold using fiberglass enhanced with a material called PDP. PDP is a noise reducing material, and fiberglass was chosen for its light weight; saving us nearly 5 pounds when compared to the stock hood. PDP is a constrained layer damping foil for laminating into fiberglass panels to improve sound transmission loss and absorb structural acoustic energy [8]. It interacts with the structure of the composite material to dampen sound waves.

To further reduce noise, acoustic melamine was added to the underside of the hood. The particular melamine we used is called Hushcloth Melamine and was chosen for its light weight, excellent sound absorption, and high heat resistance. The high heat resistance is particularly important because the lack of hood vents leads to extremely high under-hood temperatures; and even if the melamine's maximum temperature is reached, it will char rather than burn. Other types of sound absorbing foams are much more flammable and would create a fire hazard. While other materials have higher sound absorption coefficients (figure 1), the Hushcloth Melamine is the best foam for fire resistance and absorbs sound better than other fire resistant materials, like fiberglass. It also works the best in the 1 kHz to 4 kHz range, which is the most common weighted frequency in the dBA scale with our engine setup.

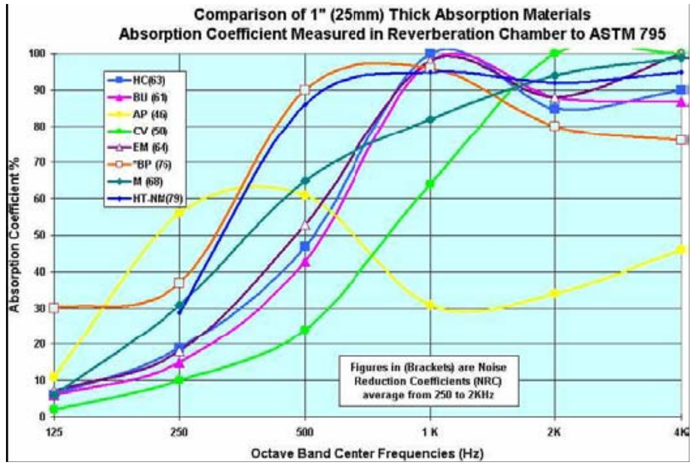


Figure 12: Sound transmission through various commercially available sound absorbing materials.
Melamine foam (M) (dark green) is used in the snowmobile hood [8].

TRACK SELECTION

The track on a snowmobile is one of the main contributors to noise emissions; for this reason we have looked to our supplier for what they have considered to be a quiet track. Through talking to our supplier Camoplast, we have decided to use their one and a quarter inch Ripsaw track. This track has been tested by Camoplast to be their quietest track when pre-holed with 144 stud holes [9]. The Ripsaw track features crescent shaped lugs which improve hard pack snow handling and acceleration. The deeper lug design allows for better deep snow performance.

STUDS

For the first time in 2007 the UB CSC team has opted to run studs in the track. Due to the under powered engine we have opted to run studs to improve upon our acceleration. To keep the noise emissions minimal we decided to use 48 Woody's Gold Digger 1.325 inch studs with square aluminum backers to reduce weight. The studs utilize the pre-holed pattern and are installed on every other bar on the track.

NOISE REDUCTION APPROACH

The reduction of noise was a large concern for the UB team this year. To tackle this challenge, a number of cutting edge materials from American Acoustical Products were used. A vinyl based matting called VE was used to reduce resonating frequencies coming from areas within the snowmobile. VE is used to lower noise heard from a resonating structure, which is ideal for the underside of a snowmobile tunnel. Noise from the moving track and rear suspension components are trapped in this cavity and resonate. With the use of VE on the interior of the tunnel, unwanted frequencies and audible noises will be absorbed and reduced. Two other materials that were used to reduce noise are Millennium Metal and the aforementioned Hushcloth Melamine.

Millennium Metal is an aluminum honeycomb that is used to absorb low frequency noises, and its performance increases when used in conjunction with Hushcloth Melamine. In response the engine's fuel knock, close fitting millennium metal shields were used to attenuate the fuel knock sound. Using millennium metal attenuates the sounds coming from the engine, which allows the Hushcloth Melamine to attenuate the rest of the noise. American Acoustical has been implementing this technology with diesel busses and has proven a ten decibel decrease in engine noise by using the close fitting shields [10].

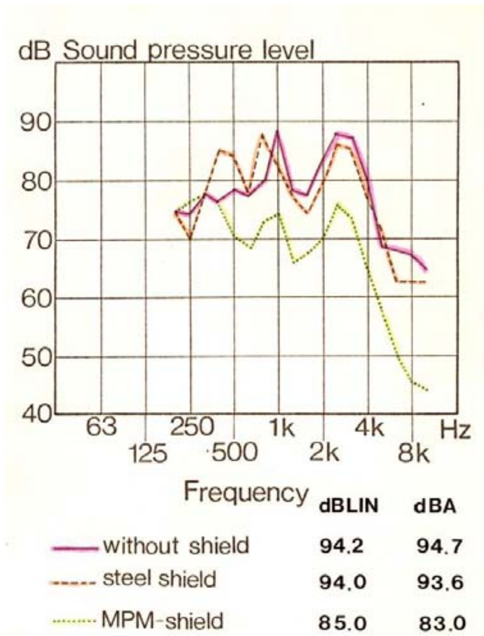


Figure 13: Close Fitting Shields Comparison

The shields that we have implemented are the serpentine belt cover, clutch cover and engine cover. The belt guard was designed and made out of 1/8" aluminum for rider safety and is securely fastened to the engine in two places using bolts, and also held to the chassis using a nut and bolt. This allows it to be easily removed from the engine, while still being held securely in place. The underside of the guard is covered in VE. To reduce the resonant sound emitted from the serpentine belt and pulleys. The clutch cover is designed similar to the belt guard, but instead of aluminum, titanium was chosen as a more suitable material for its strength and light weight. VE is again used under the clutch cover to dampen the resonant frequencies. The clutch cover is fastened to the chassis with three zeus clips which, allow for easy access to the belt as well as a tight fit. The final cover is the millennium metal cover that was created to encase the head and base of the engine along with the alternator. These three covers encase the front and two sides of the engine while the rear of the engine is left clear. The noise from the rear of the engine has to travel through the tank and the seat to escape the chassis; thus a rear cover is not necessary and just adds weight to the snowmobile.

CONCLUSION

The UB CSC Team has created a snowmobile that has never been brought to the challenge before. The team has also created more of a long term plan in which the future of the team and the goals for each year are much more attainable. The UB team's diesel driven snowmobile may not be perfect in its first year, but with the advances in diesel technology the engine will become a more powerful plant that runs cleaner and quieter than ever before. Implementing the Daihatsu diesel and an after treatment exhaust system will create a competitive sled for the 2007 competition year. Along with a diesel engine and an after treatment exhaust we used successful theories of sound dampening from previous years and a competition proven chassis to develop a competitive snowmobile. The goal of this year was to think outside of the box, become more innovative, do something nobody has done before, and realize where improvements can be made over the next few years. We firmly believe that this sled embodies each one of those goals and has fulfilled them to the approval of the 2007 UB CSC Team.

REFERENCES

1. The Society of Automotive Engineers, The SAE Clean Snowmobile Challenge 2007 Rules: 2006

2. Heywood, John B. Internal Combustion Engine Fundamentals. Mcgraw-Hill SEM: 1988

3. Pulkrabek, Willard W. Engineering Fundamentals of the Internal Combustion Engine. Prentice Hall: 1997

4. Frank P. Incropera, David P. DeWitt, Fundamentals of Mass and Heat Transfer, 4th edition, John Wiley & Sons: 1996

5. “Exhaust Gas Aftertreatment for Diesel Engines”, Emitec: 2007.

6. Fox Racing Shocks, http://www.foxracingshox.com/fox_snowmobile/snowmobile_index.htm

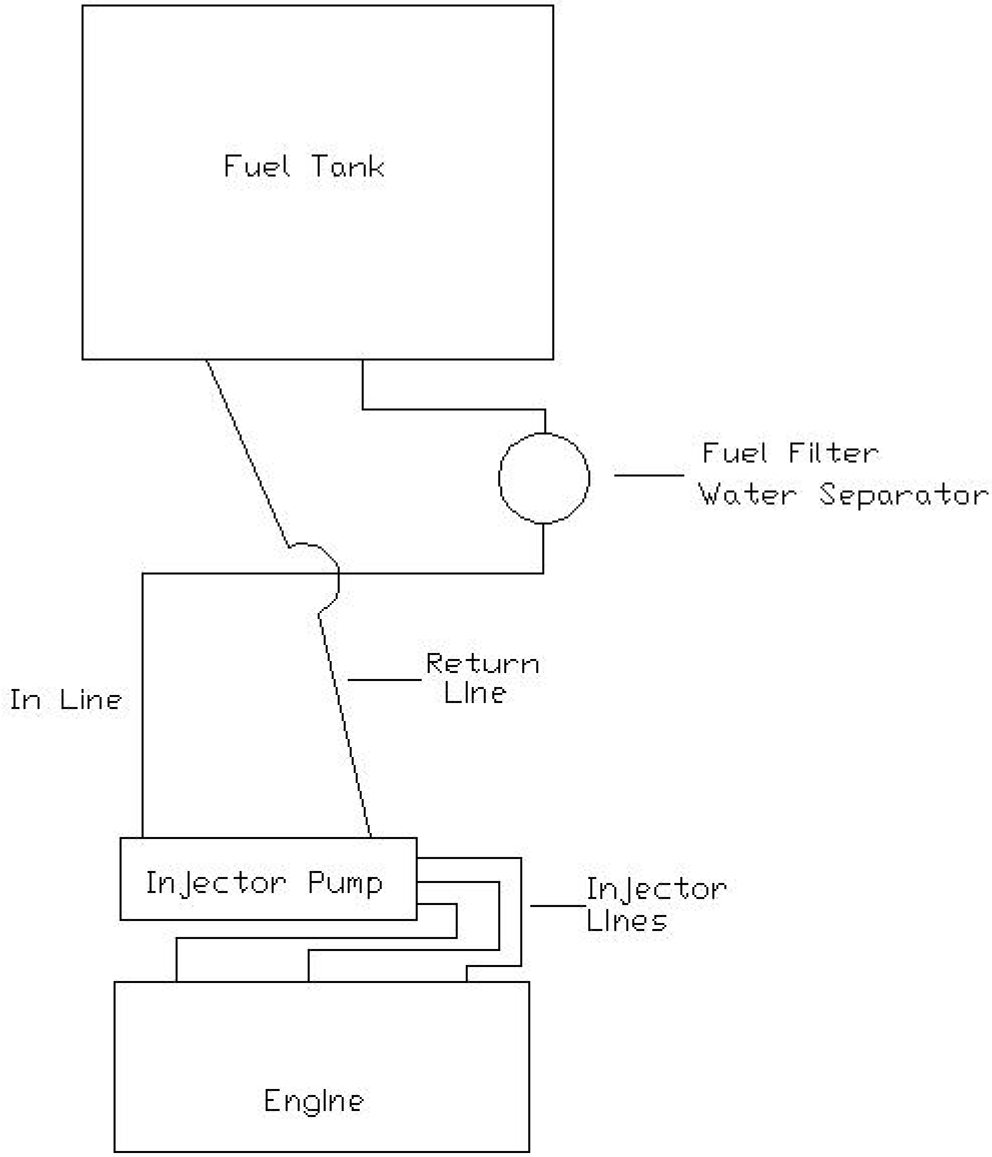
7. Amazon.com, C&A Skis, http://www.amazon.com/C-A-XT-Pro-Skis/dp/B000A1MGAQ

8. “Fiberglass Damping”, American Acoustical Products: 2003

9. Jason Davis. Personal Interviews, Camoplast. January 2007.

10. “Practical Aspects of Bus Noise Control”, American Acoustical Products: 2003.

APPENDIX A: Fuel System Diagram



APPENDIX B: Wiring Diagram