North Dakota State University – Clean Snowmobile Challenge

Scott Becker, Austin Bosse, Nick Dirnberger, Tim Novak, Keenan Nygaard, Ethan Peterson, Eric Silvers, James Tibbles

NDSU SAE CSC Team

Abstract

The clean snowmobile team at North Dakota State University has developed a clean, quiet, and efficient diesel utility class snowmobile. The snowmobile is designed to compete in the Society of Automotive Engineers' (SAE) 2017 Clean Snowmobile Challenge. The snowmobile is built around a turbo-charged three cylinder 904cc Yanmar diesel engine mounted in a 2015 Polaris Widetrak LX chassis. Due to high engine temperatures and a developing knocking sound, the Yanmar engine was rebuilt to ensure the reliability and performance of the engine. An IHI RHF3 turbocharger has been added to the engine to increase power output and efficiency. In order to exceed the emission standards set forth by the competition, and further improve prior teams' performance, a MagnaFlow stainless steel catalytic converter has been installed behind a 2009 Volkswagen TDI diesel particulate filter and diesel oxidation catalyst to reduce carbon monoxide, hydrocarbons, nitrous oxides, and soot emissions. Painting the chassis and other components with noise dampening paint will greatly reduce vibrational noise produced by the engine, drivetrain, and suspension. In addition, adding a noise dampening skirt will help contain the noise produced from the track and the rear suspension. Innovative ways have been incorporated in every aspect of the snowmobile's design, from reducing the sound and improving emissions to redesigning engine mounts.

Introduction

Some growing challenges in today's engineering world are to design equipment to be more efficient, cost effective, produce less particulates, lightweight, safe, and depending on the application a higher power output. A few large industries where these challenges can be seen are the automotive, construction, and agricultural industry. Every year, companies need to meet new efficiency and emission regulations to continue production. This creates a great demand for engineers to overcome these challenges through complex designs on high priority deadlines.

Producing clean, fuel efficient, and noise controlled snowmobiles is a growing industry. This is due to a growing need for transportation through sensitive areas like National Parks where impacts from unnatural disturbances are strictly enforced. This includes but is not limited to damaging forests floors, introducing pollutions, and high levels of noise.

The Clean Snowmobile Challenge, hosted by the Society of Automotive Engineers, is an international competition to help enhance engineering student's skills in project management and engineering design. The basis of the competition is to have teams produce cost effective, clean snowmobiles that will be accepted in sensitive areas such as National Parks [4]. This will be accomplished through designing snowmobiles to emit less unburned hydrocarbons, carbon monoxide, nitrous oxide emissions, and soot. The snowmobiles engineered will be specifically designed to be ridden on groomed trails. Each year the Clean Snowmobile Competition Rules Committee evaluates and changes the rules and competition to stay up to date with present engineering challenges. Some of the areas in which the snowmobiles will be judged are as follows: emissions, noise, acceleration, handling, fuel economy, static display, cold start, design, and design paper.

Engine and Turbocharger

Engines Considered

There were two design options to decide between regarding the choice to participate in the diesel utility class. The first option was to reuse the Yanmar engine that had been used in past years. The Yanmar engine can be seen in Figure 1.

Figure 1. Yanmar 3TNM72 engine

This engine required a rebuilt kit due to a knocking noise that had become more apparent throughout the competition last year. This engine had been rebuilt multiple times already.

The second option considered was to start new, by obtaining a complete different engine. The engine that was debated was the Mercedes three-cylinder 0.8 Liter diesel engine and can be seen in Figure 2.

Figure 2. Mercedes Smart Fortwo 3-Cylinder Diesel Engine

This engine would outperform the Yanmar engine in horsepower, emissions, and fuel management. The Mercedes diesel engine is the smallest diesel engine with one of the more advanced fuel management systems on the market. This option would allow the engine to be competitive for upcoming years. This option would require locating the desired engine, obtaining it, and getting it running standalone. Both engines in consideration have a similar issue of packaging constraints. This constraint was that the engine compartment was originally designed to fit a gasoline engine, not to house a heavier and bulkier diesel engine.

Engine Selected

The engine first decided upon was Mercedes but due to time and budgetary constraints, the team was forced to change the project scope and incorporate the Yanmar 3TNM72 engine instead. This was the result of the design team experiencing many setbacks during the fall semester. These caused delays in the acquisition of the Mercedes diesel engine that was ideal for the use in this year's Clean Snowmobile Challenge competition. It ended up that the engine was finally acquired near the end of November and with a cost of 80% of the allotted funds from the NDSU ME Department. However, the sellers did not follow the explicit instructions given by cutting the wiring harness. This meant that a new wiring harness was needed. The new engine will also need a standalone ECU to operate, which costs upwards of $2000 for the hardware and more for the programs and programming necessary. Considering the competition for Clean Snowmobile is in the beginning of March, this only gave the team four months and a less than practical amount of funds to design, fabricate, and test a competitive snowmobile utilizing this new engine that needs many additional components of its own. This feat was unachievable with the time and funding at hand. The design team came together at the end 2016 and had meetings regarding how to move forward. It was decided that there was no way that the team could produce a competitive snowmobile by March, 2017 with the funds and time provided using the Mercedes engine. The team decided to pursue the option of using the engine used in last year's design, a Yanmar 3TNM72, being that it is proven to run and the team did relatively well at competition the previous year.

There are benefits of using the engine from last year, although there are cons as well. The Yanmar is mechanically operated and has no need for an ECU while the Mercedes requires an ECU to tell it how to operate. Using the Yanmar engine eliminates the need to purchase an ECU with the current budget allotment. However, the programmability of the ECU would have allowed for customization of the engine parameters and in the long-run would have helped produce a more competitive snowmobile for competition. Another benefit of using the Yanmar engine is that this engine has more practical engine mounting placement when considering the structure designs of the snowmobile chassis. The mounts used last year have been modified to fit the new chassis, which eliminated some of the cost for fabricating new mounts. The output shaft has also already been designed for the Yanmar which eliminates another expensive fabrication cost that would result from using the Mercedes engine and having to fabricate an output shaft for that engine. Despite these conveniences, the Yanmar engine was producing a loud knocking sound while operating. To diagnose the problem, the team decided on a complete engine teardown and was taken apart to find a cracked piston head in the middle cylinder as well as a hairline crack in the cylinder head between the middle cylinder and a water jacket. The piston was replaced with one from a spare parts engine that was kept from previously used engines. The cylinder head was also taken from the spare parts engine and taken to a machine shop to be refinished and implemented in the rebuild. The Yanmar was cleaned piece by piece and then reassembled using the replacement piston and cylinder head along with replacing all the bearings, valve seats, and head gasket with new factory parts.

Turbocharger

The turbocharger utilized for this year's competition was the same used on last year's engine. The turbocharger used was an IHI RHF3 turbocharger. This turbocharger was designed and rated for engines with a displacement of 1000-4000 cc with a power output of 20-100 horsepower. With the Yanmar's displacement of 904 cc, it fell below the desirable range of displacement but with its power output of 23.8 horsepower, made it an ideal choice for the snowmobile's application.

Drivetrain

Clutch Mechanism

The snowmobile transmits power from the engine to the track via two different clutches, the primary clutch and a secondary clutch. These clutches make up the continuous variable transmission and can be seen below in Figure 3.

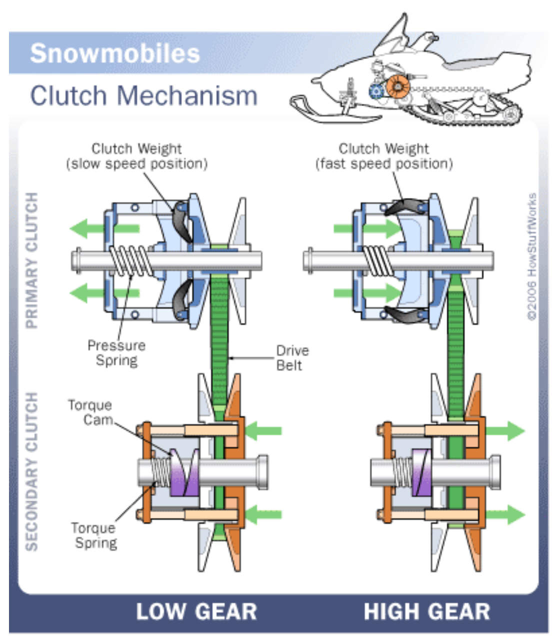

Figure 3. Snowmobile clutch mechanism

This mechanism is more commonly referred to as a CVT. Both the primary and secondary clutches were donated this year from TEAM Industries. The primary clutch has weights that were sized correctly to compensate for the low revolutions per minute (RPM's) associated with diesel engines. This allowed for the optimization of power and torque transfer to the track.

Output Shaft and Spacer

An output shaft had to be custom designed in order to transfer the power of the engine to the primary clutch of the CVT. The diesel engine being used this year is the same engine that was used in last year's snowmobile. Therefore the same output shaft and spacer from last year's snowmobile will be reused in the design this year. This output shaft allowed the primary clutch to attach to the output of the Yanmar engine. The material used for the output shaft was 321 annealed steal which has a yield strength of 234.42 MPa. Finite element analysis (FEA) was performed on the output shaft and spacer by the previous NDSU Clean Snowmobile team. Both the output shaft and the spacer were analyzed based on an applied torque of 160 foot pounds which was determined by applying a factor of safety of 2.5 to the maximum output torque of the Yanmar engine. The highest stress induced on the spacer was 10.42 MPa giving the spacer a factor of safety of 22.5 based on the yield strength. The highest stress induced on the output shaft was 85.69 MPa giving the output shaft a factor of safety of 2.74. The FEA results for both the output shaft and the spacer can be seen in Figure 4 and Figure 5.

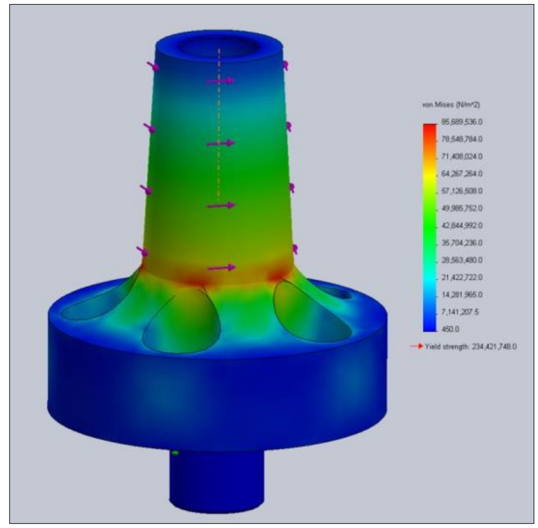

Figure 4. FEA analysis of the output shaft

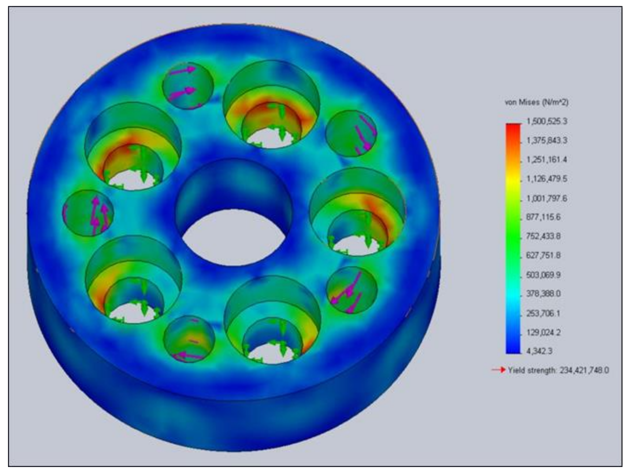

Figure 5. FEA analysis of the output spacer

Chassis Modification

Engine Mounts

Originally the team needed to design new engine mounts for the Mercedes diesel engine. These mounts needed to be able to withstand engine vibrations, engine weight, and the thrusting motion created by the engine when accelerating. It was determined that the new mounts should be adjustable, lightweight, and as compact as possible. Making the mounts adjustable allows for possible relocation or alignment changes to make the engine fit into the chassis. Not only does the engine need to fit in the snowmobile, it also needs to line up with secondary clutch and transmission components.

After it was determined to use last year's Yanmar engine the team had to come up with a different plan of action. Engine mounts from a previous snowmobile were modified to fit this year's application. The previous mounts were adjustable, lightweight, and featured rubber bushings to help with vibrations and engine movement. The front engine mounts bolted perfectly into the new chassis with little modification. As shown in Figure 6, the front mounts had to be cut in half to allow clearance for the steering rod. Cutting the front mounts in half also required the mounting holes to be relocated. The rear mounts needed to be raised to provide adequate height to keep the engine level and to avoid the oil pan from hitting the steering. This was achieved by making three 1.75 inch thick spacers to go underneath the engine mounts, as seen in Figure 7. The rear engine mount also had to be cut in half due to clearance issues. The bolts holding the engine to the mounts are four inches long and can only be put in from one direction due to the engine's flywheel location. This becomes a problem as the bolt cannot be removed because the other engine mount is in the way. For this reason the bolt cannot be fully remove and neither can the engine. The team decided to save time by making the second mount removable rather than machining completely new engine mounts. By making the mount removable the bolt in the other engine mount can be removed flawlessly. The removable engine mount is bolted to the spacers with four ⅜ inch grade eight bolts. FEA was conducted to see what kind of stress the engine mount and these bolts would be under. Figure 8 shows the concentrated stress areas around the upper two holes. This is due to the angle at which the mount is positioned and the direction the engine rotates when operating. The maximum stress observed was 1949.3 psi. The team deemed these results acceptable for the material and hardware used.

Figure 6. Front engine mounts and steering rod

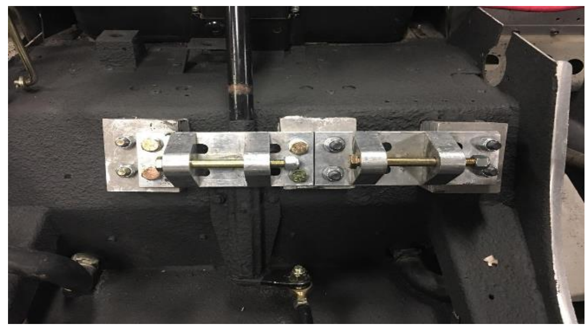

Figure 7. Rear engine mounts with spacers

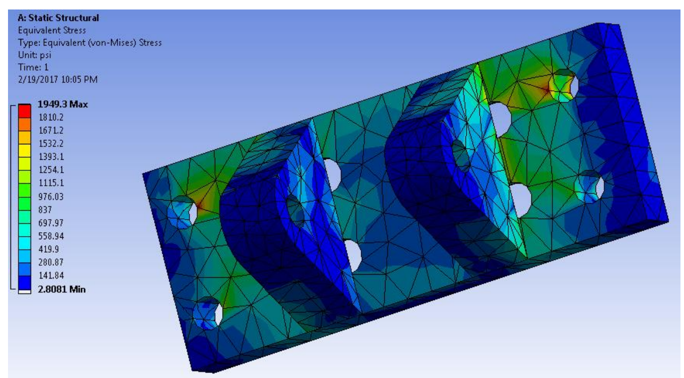

Figure 8. Rear engine mount with max stress of 1949.3 psi

Weight Distribution

With the extra weight of the diesel engine, the team was concerned about weight distribution. The extra weight on the front skis could affect the snowmobiles' traction and towing capabilities. This year's chassis features an adjustable suspension that allows the operator to put more or less pressure on the skis with the turn of a knob. The team tested this feature by placing the snowmobile on top of four scales as shown in Figure 9. Two scales were placed under the skis and the other two were placed at the front and rear of the track. Weights at each scale were recorded with and without riders with the suspension adjusted at different points. The results showed that anywhere from 10 to 40 pounds could be shifted from the skis to the track. The extra pressure on the track will provide better traction when towing. It was also noted that less weight on the front skis may make the snowmobile harder to steer. This would require physical dynamic testing and was decided to be done at a later date. To also aid in weight distribution, the team decided to remove the diesel engine's heavy battery from the engine bay and place it at the rear most part of the tunnel. This added more downward pressure on the track and lightened up the front end, getting the snowmobile closer to original stock weight distribution.

Figure 9. Weight scale locations

Exhaust and Emissions System

The exhaust system is arguably the most important part of the snowmobile, second to the engine. Running a diesel engine in a snowmobile provides unique emission system challenges. The exhaust system must be designed to muffle the noise of the exhaust coming from the engine while ensuring proper pressure to maximize the turbo efficiency. However, the largest focus will be placed on emissions. Diesel engines release several compounds that are harmful to the environment. The primary pollutants created are nitrous oxides (NOx), carbon monoxide (CO), particulate matter (PM) and unburned hydrocarbons (HC). To prevent the release of these pollutants, several exhaust treatment components are incorporated in the snowmobiles exhaust system. The typical diesel exhaust system has both a Diesel Oxidation Catalyst (DOC) and Diesel Particulate Filter (DPF). The DOC and DPF are often packaged together in a single housing, as is the case with the first component of the emissions treatment system on the snowmobile this year. The exhaust first flows through the DOC and then through the DPF before being omitted to the atmosphere.

Diesel Oxidation Catalyst

The DOCs purpose is to reduce the release of CO, HC and PM. The catalyst is formed of a substrate that is coated with a precious metal. When the metal is heated to high temperatures, a reaction occurs. This reaction oxidizes CO, HC and PM to the compounds CO_2 and H_2O. If selected properly, a functioning DOC can result in reductions of PM by 20 to 40%, HC by 40 to 75%, and CO by 10 to 60% according to the EPA [2]. In order to create the proper catalytic reaction, high temperatures must be reached. The exhaust temperature must exceed 300°C in order to reach the desired 90% efficiency level.

Diesel Particulate Filter

After the exhaust passes through the DOC it enters into the DPF. The primary function of the DPF is to remove particulate matter (PM) or soot from the exhaust stream. The DPF is similar to most filters in the sense that it traps the undesired PM before it can be emitted into the environment. The DPF is typically made out of a ceramic material that can withstand high temperatures. When the PM is trapped in the ceramic material it is burned into ash and converted into non-harmful emissions. This is called a regeneration process. There are two types of regeneration, passive and active. Active generation requires a fuel additive to be released into the DPF. By adding fuel to the DPF, ignition occurs creating high temperatures that burn and essentially clean the filter. Passive regeneration requires no fuel additive. Instead the temperatures created by the engine are high enough to burn the PM trapped in the DPF.

Proper application of a DPF can result in particulate matter reductions greater than 85% [3].

Emissions Treatments

The system incorporated in this year's design is a diesel oxidation catalyst (DOC) and diesel particulate filter (DPF) system of a 2009 Volkswagen TDI followed by a diesel catalytic converter donated by MagnaFlow. The Volkswagen system is a wall-flow system that contains a DOC and DPF in a single housing and is shown in Figure 10 below.

Figure 10. Volkswagen Wall Flow DOC/DPF system

Last year's team utilized the Volkswagen system and performed very well when tested for particulates but poorly when the exhaust was tested for Nitrous Oxides (NOx). However, since the design last year did not incorporate a built-in regeneration cycle to self-clean the system, the soot particles simply built up inside the ceramic filters. Therefore, the Volkswagen system was heated up and cleaned out using compressed air to ensure maximum performance this year. The Volkswagen DOC/DPF will filter out the PM, CO, and HC and the MagnaFlow catalytic converter eliminates the remaining NOx output. The MagnaFlow catalytic converter is a universal diesel stainless steel catalytic converter that has a ceramic substrate and can be seen in Figure 11 below.

Figure 11. MagnaFlow Diesel Catalytic Converter

Track Modifications

Track Selection

The stock track that comes with the snowmobile is a Polaris 156 x 20 inch [1]. This track has one inch non-studded lugs. This track did not suit the team's needs due to the fact that it is not studded. Having a pre-studded/studded track would allow the sled to have better traction on hard-pack snow and ice. This would greatly help during the drawbar pull event of competition. One benefit to manually studding a track is that the stud pattern can be easily customizable and has excellent grip on ice, however installing studs is extremely time consuming. Another downfall to a studded track is that it can be a bit noisier than a non-studded track. The team decided to go with a pre-studded track for both time and money's sake as the team was able to get a heavy duty pre-studded utility traction track donated by CAMSO. This track is the same size as the stock Polaris track, but instead is pre-studded and has 1.25 inch tall lugs. The longer lugs will certainly help with traction in on ice and hard packed snow.

Big Wheel Kit

In previous years the team has equipped the snowmobile with an aftermarket big wheel kit. A big wheel kit replaces the farthest rear idler wheels with larger diameter ones. The larger diameter wheels allow the track to have less rolling resistance, thus making the system more efficient. The wheel also has more contact with the track which could reduce slack in track that causes extra noise. Most aftermarket kits consist of two idler wheels placed inside the suspension rails. This is very common for snowmobiles with 15 inch or 16 inch wide tracks. However, Polaris' Widetrak snowmobile has four rear idler wheels with a 20" wide track. There are no kits on the market for a snowmobile with a track this wide. Also, a two-wheel kit would likely not be able to support such a wide track. These concerns led the team to design a custom big wheel kit for the Widetrak chassis. The kit consists of a four-wheel design and relocates the axle to accommodate the larger wheels as seen in Figure 12.

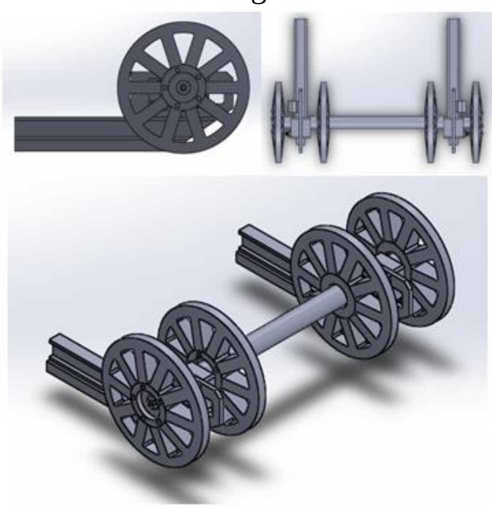

Figure 12. Big wheel kit design

The kit upgrades the stock composite rubber wheels to larger hard plastic wheels. Due to space limitations the wheels were only able to increase by one inch in diameter. To save money on machining costs larger stock wheels from a different commercial snowmobile were implemented rather than billet aluminum wheels. The larger wheels reduce the rolling resistance of the snowmobile creating a more efficient system. Due to the conditions that these parts will be encountering, the team's goal was to make the parts out of aluminum. To ensure these parts had adequate strength FEA was conducted. The part of most concern was the kit's axle. The axle was tested as 6061 T6 aluminum and experienced a 520 pound load at the location of the idler wheels. Physical testing showed that the four idler wheels would experience a static load of 260 pounds. A factor of safety of two was added to achieve the 520 pound load. This loading caused no deflection in the axle. This can be seen in Figure 13. It was decided that the big wheel kits' parts were adequate and the design was finalized.

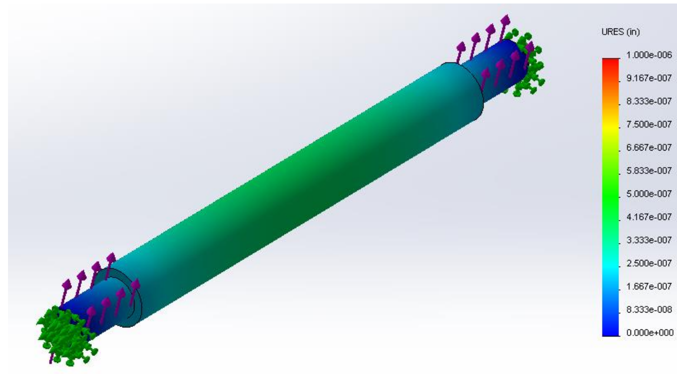

Figure 13. Total Deformation of Big wheel axis

Sound Treatment

Noise Dampening Paint

One area that the team wanted to improve on was noise reduction. Noise dampening paint was one of the ideas to help prevent noise. As research was conducted, LizardSkin Sound Control paint was viewed as a viable option. The advantages that LizardSkin Sound Control paint had were that when it is applied it isn't very thick, has test results showing that it reduces noise, can handle cold temperature, is wear resistant, and is easy to apply. After LizardSkin Sound Control paint was received testing was performed on a sample material that was the same material as the chassis' tunnel. To test the paint, the test material was not painted and clamped to the table. A 1.5 inch section of the material was clamped to the table and the rest of the sample material was hanging over the edge. A test object that weighed 1.284 pounds was dropped from a height of 1.375 inches for every trial onto the sample material. A total of 20 trials were performed on the test material without any LizardSkin Sound Control paint applied. The results were recorded and can be seen in Figure 14.

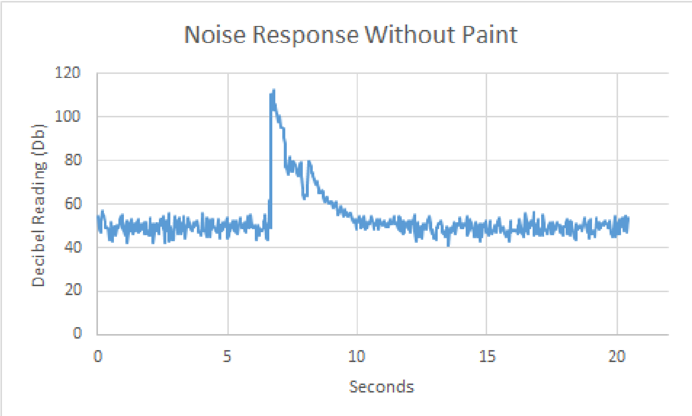

Figure 14. Noise Response of test material without LizardSkin paint

The average of the maximum noise produced for the sample was determined to be 104.08 decibels. After that one side of the test material was painted with LizardSkin Sound Control. The same test was performed with 20 trials and the data was recorded. The noise response of this test can be seen in Figure 15.

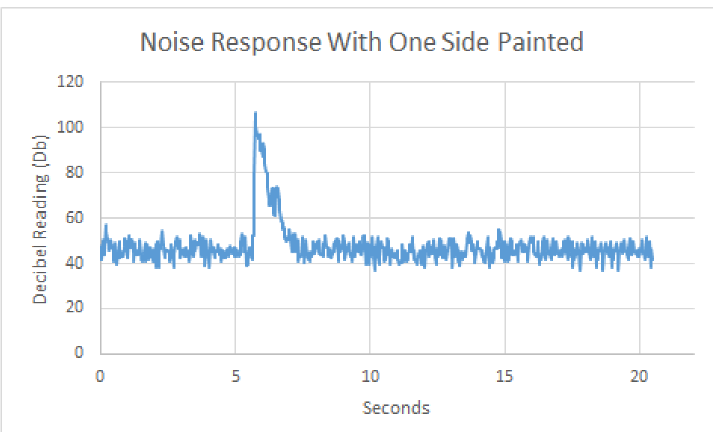

Figure 15. Noise Response of test material with LizardSkin painted on one side

The average of the maximum noise produced by the sample was determined to be 95.78 decibels. From there the other side of the test material was painted so that both sides were now painted. The same test was performed with 20 trials with the data was recorded. The noise response of this test can be seen in Figure 16.

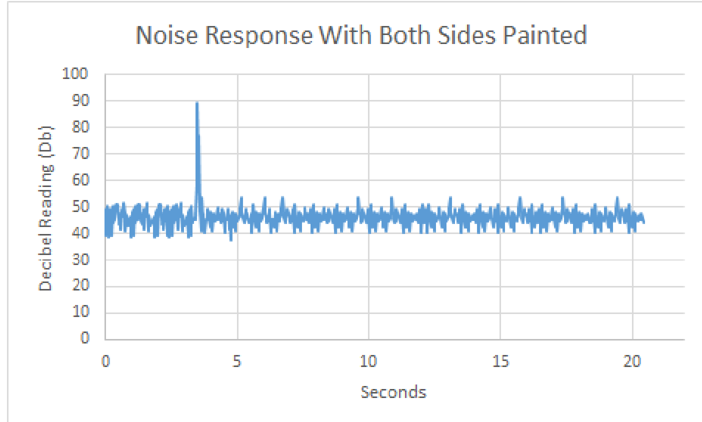

Figure 16. Noise Response of test material with LizardSkin painted on both sides

The average of the maximum noise produced by the sample was determined to be 84.55 decibels. The testes that were completed had outlier testing performed on them and outliers were removed from the data to calculate the averages.

From the results a 95% confidence intervals were performed on the average peak decibels. When one painted side of the test material was compared to no paint the average max peak decibels were reduced by 6.92 to 9.68 decibels with the 95% confidence interval applied. When two painted sides of the test material were compared to no paint the average max peak decibels were reduced by 17.18 to 21.88 decibels with the 95% confidence interval applied. When comparing one painted side of the test material to two painted sides the average max peak decibels was reduced by 8.72 to 13.74 decibels with the 95% confidence interval applied. The team decided to also look into how well the LizardSkin Sound Control paint could reduce noise over time. The time of impact of the falling object to the time when no noise was given off from the test material is the time it took for the test material to quiet down. The results of the experiment showed that when both sides were painted the test material took around 0.40 seconds to quiet down. When one side of the test material was painted the test material took roughly 1.22 seconds to quiet down. With no paint applied to the test material the time it took for the test material to quiet down was about 3.04 seconds. From those results the team determined that it would be beneficial to apply LizardSkin Sound Control paint to both sides of the tunnel and everywhere else that had exposed aluminum to best reduce sound.

Noise Dampening Skirt

In order to reduce some of the noise caused by the rear suspension and track a few ideas were considered. One would be to try to add noise dampening materials and designs into the suspension parts and track. The other would be to try to contain this noise and ultimately reduce the overall noise caused by the snowmobile. Some ideas on how to contain the noise were contemplated but a skirting design was ultimately chosen due to its easy and time saving design. The material for the skirting and the mounting of the skirt were the two major keys of design. The design needed to ensure that the skirt could reach as close to the ground as possible but yet still be able to give when the suspension was compressed during use. Any type of rigid material that would be used would need to be designed so that it retracts when in compression; however, this design limits how close the skirt can be to the ground and would also take up more space that doesn't exist on the chassis. In order to maximize the length of the skirt and to save space a flexible nylon bristle design was implemented. The skirt installed on the underside of the running boards and all the way back to the mud flap. The nylon bristle offers great flexibility, bend recovery, water resistance, and durability. This selection is the most cost effective while offering great clearance and noise reduction. This design will ultimately help contain the noise in the chassis and produce a more successful overall design.

Conclusion

Each year, engineers are tasked with the duty of designing and producing more technologically advanced equipment. With this, engineers need to address the issues of emitting lower emissions, fuel efficiency, ergonomics, costs, and safety. The North Dakota State University's Clean Snowmobile Team was tasked with a similar challenge for a snowmobile design to be clean and efficient. The Clean Snowmobile Competition focused on producing a quiet, clean, efficient, and reliable snowmobile that would exceed the criteria set forth by the competition. These were accomplished with the addition of a rebuilt diesel 904 cc Yanmar engine with an IHI RHF3 turbocharger into a 2015 Polaris Widetrak LX chassis. With this diesel engine, challenges were created that needed to be addressed. Diesel engines aren't known for their emission without any after treatment, this created the challenge of lowering emissions. Emissions were lowered through modifying the exhaust system by mounting a DOC/DPF with a stainless steel catalyst behind it reducing unburned hydrocarbons, carbon monoxide, nitrous oxide, and soot particles. A challenge that arose with the chassis was how to reduce noise of the snowmobile. As with all moving parts, there is going to be noise associated with everything. The noise dampening paint was used to help reduce vibrational noise produced by the engine, drivetrain, and suspension. The noise dampening skirt was created to help contain all of the noise that could not be reduced. Those methods were the main ideas of reducing the sound output of the snowmobile. Overcoming these challenges provided each team member valuable skills and knowledge that can be used in future applications in the industry. This year the team's goals were to reduce emissions and noise levels, complete the endurance run, increase top speed and design paper score while maintaining power output and reliability. By having a reliable snowmobile that can be used for years to come, will allow for more time to be spent on innovation, design, and improving performance for the Clean Snowmobile Challenge.

References

1. "550 WideTrak LX." 2017 Polaris 550 WideTrak LX Snowmobile. Accessed February 20, 2017. http://www.polaris.com/en-us/snowmobiles/550-widetrak-lx.
2. EPA, U.S. Technical Bulletin: Diesel Oxidation Catalyst General Information (EPA-420-F-10-031) (May 2010).
3. EPA, U.S. Technical Bulletin: Diesel Particulate Filter Operation and Maintenance (EPA-420-F-10-027) (May 2010)
4. "SAE Collegiate Design Series." About - SAE Clean Snowmobile Challenge - SAE Collegiate Design Series - Students - SAE International. N.p., n.d. Web. 20 Feb. 2017.
5. SAE International, ed. 2017 SAE Clean Snowmobile Challenge Rules. U.S.A.: SAE, 2016.

Definitions/Abbreviations

SAE	Society of Automotive Engineers
FEA	Finite Element Analysis
MSRP	Manufacturer's Suggested Retail Price
CSC	Clean Snowmobile Challenge
NOx	Nitrous Oxides
DOC	Diesel Oxidation Catalyst
DPF	Diesel Particulate Filter
HC	Hydrocarbons
PM	Particulate Matter
CO	Carbon Monoxide
CVT	Continuous Variable Transmission

Appendix

Table 1: Results Noise Response performed on LizardSkin Sound Control paint for max peak

Test Material	Average max peak noise (dB)	Standard Deviation in (dB)	95% Confidence Interval of average max peak noise (dB)
No paint applied	**104.08**	**1.33**	**104.08 ± 0.61**
One side of material painted	**95.78**	**1.67**	**95.78 ± 0.77**
Both sides of material painted	**84.55**	**3.3**	**84.55 ± 1.74**

Table 2: Results Noise Response performed on LizardSkin Sound Control paint for time required to quiet down

Test Material	Time Taken for Test Material to Quiet Down
No paint applied	**3.04 seconds**
One side of material painted	**1.22 seconds**
Both sides of material painted	**0.40 seconds**