NDSU 2018 SAE Clean Snowmobile Challenge

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Abstract

The North Dakota State University Clean Snowmobile Challenge Team set the goal to compete in the 2018 Clean Snowmobile Challenge. Researching previous competitions, it was determined that the focal point of the teams effort and resources will be focused in three specific judging criteria, while remaining competitive in the remaining categories. Subjective and objective noise stand out as large point contributors and something that the team is pushing to excel in with this years build. Penalty points in this category have riddled NDSU's clean snow team in the past. This year, extra precautions have been implemented to avoid penalties. The second main category that the team is striving to perform well in is the fuel economy and lab emissions category. With the correct ECU, the snowmobile can be optimized and adjusted to provide optimal fuel economy. Lab emissions will be reduced by the exhaust system, which utilizes a diesel particulate filter (DPF) and a catalytic converter. The final main categories that the team wants to be competitive in are the in-service events, such as acceleration and the draw bar pull. The use of a new trail oriented track that is studded will allow the team to become effective competitors in the in-service events. The design and implementation of this snowmobile will help to lead and inspire the growing market of clean utility snowmobiles around the world.

Introduction

Snowmobiling is one of the most popular sports that people enjoy during the winter in the snowing area. However, snowmobiles, like automobiles, produce pollution and contributes to global issues. Snowmobiles that produce less amounts of pollution will be beneficial to the world. In the SAE clean snowmobile challenge, there are many engineering decisions that were made to solve this environmental problem.

The performance of snowmobile depend on the design engine that would be able to get along with other components on the chassis. To achieve some of the team goals, the snowmobile will have to meet the requirement of the following events. First, for lab emission, the snowmobile have to produce the least amount of hydrocarbons (THC), Carbon Monoxide (CO), Nitrogen Oxides (NOx), and soot during the lab emission event [5]. The amount of THC, CO, and Nox will be used to calculate "E-score" using formula below.

$$E = \left[1 - \frac{(HC+NO_X)-15}{150}\right]*100 + \left[1 - \left(\frac{CO}{400}\right)\right]*100 \geq 100$$

Equation 1: E-score equation

Second, for fuel economy and endurance event, it has to be able to travel 100 miles with a load of 250 pounds without refueling[5]. Finally, for the noise event, the maximum sound level that the snowmobile will produce must be less than 67 dBA to pass the SAE J1161 standard[5]. With the ability to handle these three events, the snowmobile will provide the good impact to the environment. In addition, it will provide good results in the competition.

Snowmobile Selection

Figure 1: Polaris Titan XC

With the utility snowmobile industry expanding rapidly, the choice for a competition snowmobile included many great options. The final choice was a 2018 Polaris Titan XC. There are many reasons for choosing this snowmobile, starting with NDSU's long term relationship with Polaris Industries. Polaris has sponsored Bison Motorsports for many years now with many snowmobiles and parts donations. NDSU has always appreciated working with Polaris and wanted to keep the relationship going.

For model year 2018 Polaris released an all new utility snowmobile based on the AXYS chassis. This is a tremendous step up from their competitors and their previous models. For the first time a utility snowmobile has not only the capabilities of a traditional utility snowmobile but is also capable of deep snow riding and maneuverability due to the AXYS chassis.

The only major concern that the team had with the selection of the Polaris Titan was the limited amount of space in the engine bay. There are other model snowmobiles that provide much more space under the hood to accommodate a larger engine. Through researching the engine size of the stock 800cc 2-stroke motor and comparing that to some of the options for diesel engines, it was determined that the additional space needed could be overcome.

Engine Selection

The sled's primary mover, and most important component, is the engine system. Choosing and using an effective diesel engine can make or break any team competing in an automotive challenge. With customizability being a high-priority for this year's sled, the focus on engines moved toward electrically controlled systems.

The main restraint when it came to engine selection for this year's sled was largely size related. There are many diesel engines on the market today, but few small enough to fit inside of the Titan chassis. Another large factor was monetarily related; economic feasibility had to be within the team's means of purchase.

Bison motorsport's most recent diesel engine used for CSC was a YANMAR 903cc, and it was heavily considered for this years sled. However, In seeking continuous improvement from year to year, the team wanted an electronically controlled engine to allow for more optimizability. Looking elsewhere the team discovered the Mercedes-Benz OM660, a diesel used in europe for smart cars. This engine is electronically controlled which allows more optimizability compared to a mechanically controlled engine. The ability to tune the engine will allow for better performance in fuel economy and lab emissions.

The OM660 is relatively small and inexpensive when compared to its competitors. The small engine size was very beneficial to the team due to the small engine bay that the Polaris Titan has. The price of the OM660 is also an advantageous feature. This is due to the fact that this engine has been around for over 10 years and had declined in value.

The biggest detractor from moving forward with the OM660 was the fact that the engine was never used in the United States. This makes finding parts and information on the engine difficult. This one detractor was not enough to move away from this engine choice. Therefore the OM660 was chosen for its ability to be optimized, the small size, and the relatively low monetary value.

Engine Controls

With the team's decision on the OM660 engine, it was necessary to obtain or create an electrical harness, as well as an engine control unit (ECU). The electrical harness connects all of the sensors, controls, battery, and ECU together. It makes up the nervous system of the sled. Meanwhile the ECU acts as the vehicular brain, timing pumps and injectors to the pressing of the throttle via advanced programming. Together they make up the engine control system.

For the sled ECU, it was limited by availability. Due to the complex workings of the unit, it was out of the team's technical ability to create and produce in-house. Due to the OM660's usage in smart cars, most aftermarket parts were sold in europe, the engine not being sold in America [6]. The ECU found is marketed towards the retrofitting of OM660's into minicoupes. The company is based out of the UK, its name: SCS Delta. After it was confirmed that it would work for the sled, the ECU was purchased.

The remnants of the original OM660 harness were limited in length, with several connector's cut unprofessionally. Purchasing a replacement harness proved to be difficult, limited by both cost and part availability. Making the decision on fixing the original harness, steps were then made to find a wiring map for reference in repair. The wiring map was found in a mercedes service manual [7]. Now knowing what had to be acquired for the system, wires and connectors were ordered, and the layout of the harness was planned. After the harness was fixed, it was tested and verified by hooking up to the sled and running the engine successfully.

Exhaust System

The SAE clean snowmobile challenge is focused on pushing eco friendly development of winter utility and recreation vehicles. Traditional diesel engines have historically been known as, “dirty” [4], and making one environmentally friendly has been a challenge of many modern companies. Removing diesel particulates and nitrogen oxides (NOx) has been the main focus, emissive substances that harm human beings directly [1]&[2]. This responsibility has fallen partially on exhaust systems, and a high performance system is a requirement for being competitive during this competition.

With significant size constraints within the engine bay, and an overall smaller vehicle then what the OM660 is designed for, a compact exhaust system was the goal. Taking this into account, the system contains a diesel particulate filter, as well as a catalytic converter. Referencing last years competition results[3], the NDSU Bison motorsports exhaust system netted them significant success for the emissions categories. This combined with the steep cost of replacing the DPF and converter led the team to decide on keeping previous years components.

Figure 2: Diesel Particulate Filter and Catalytic Converter

The final layout of the exhaust system is to the right of the engine. Placement of the DPF must be taken into account, as it cannot be to near heat sensitive parts or components. Following is the catalytic converter, before being released to the atmosphere.

Engine Mounts

Implemented in the Titan chassis is the OM660 diesel engine. Much larger and heavier than the stock engine, the OM660 had to be retrofitted into the small engine bay, requiring entirely new engine mounts. Placement of the engine was constrained by several factors: it had to line up with the clutching system, it had to have some lateral travel for positioning, and it had to fit inside of the engine bay. The final positioning was the best option regarding those three restrictions.

One support component in the engine bay helped the decision making process immensely. Running between the two upper control arms is a stock aluminum support tube. This bar runs parallel to the crankshaft of the engine and the driveshaft of the snowmobile, meaning that if it were used to mount to, the engine could travel to and fro while maintaining its alignment with the clutch system. Because of the added forces from the engine weight on top of it, and it already being a suspension component, this aluminum tube was replaced by a 1018 mild steel solid bar. Finite element analysis (FEA) on the stock tube and replacement 1018 bar proved that the new bar was much stronger and underwent less deformation, when submitted to the same loads. Polyurethane bushings were pressed against the bar by metal clamps, that were in turn welded to brackets connect to the motor. FEA confirmed these two engine mounts could withstand both the weight and vibrations of the OM660.

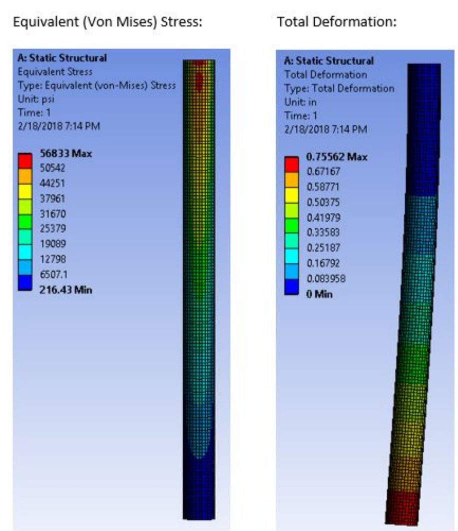

Figure 3: Stock Aluminum Crossmember

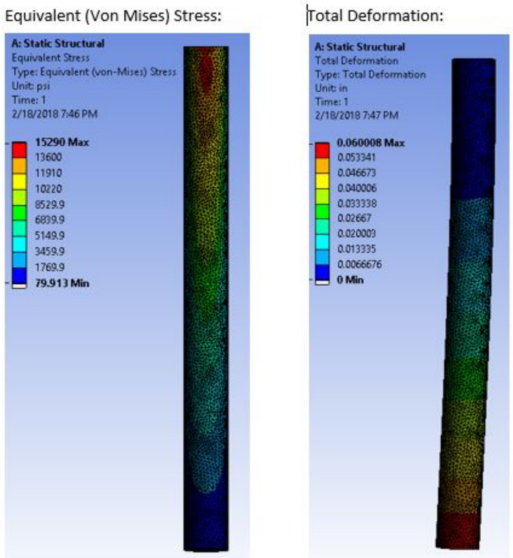

Figure 4: 1018 Steel Crossmember

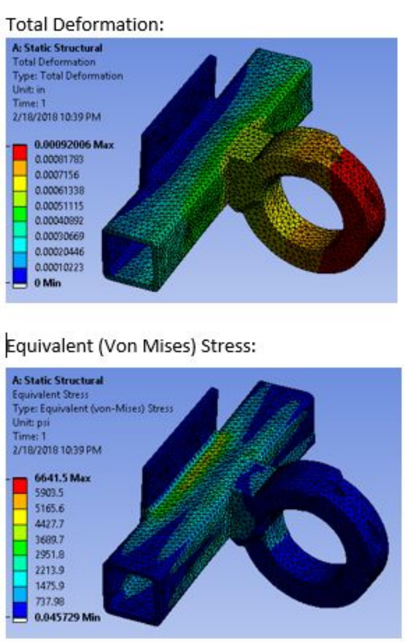

Figure 5: Engine Mount 1

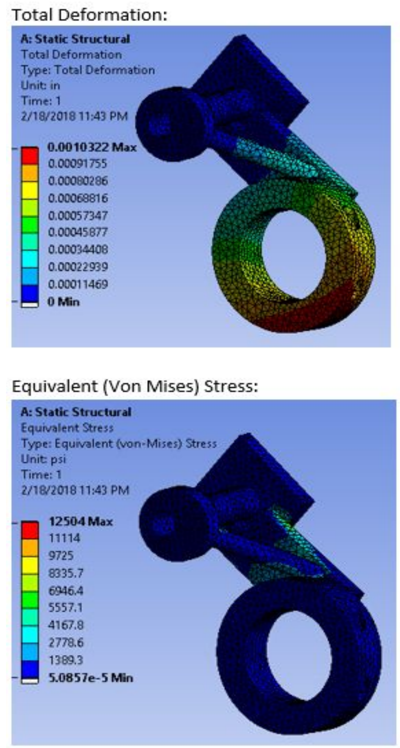

Figure 6: Engine Mount 2

The third mount is a simple metal bracket connecting to the engine bay floor. Similar to the other mounts, it was designed in CAD, analyzed in Ansys, and fabricated.

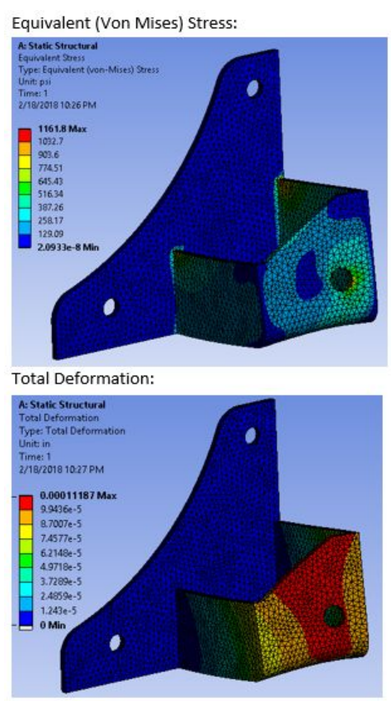

Figure 7: Engine Mount 3

Overstructure

The largest chassis modification for this year's sled is to accommodate the much larger OM660 engine. Supporting the front suspension of the sled are two bars made of 4130 - chromoly that run upwards over the engine bay, connecting to the top of the sled near the handlebars. For the stock Titan model engine, these supports ran directly from one point to the other. The OM660 engine that was used in this years competition takes up much more space, and it sits 6 in. higher than the stock motor. This increased height restricts the support bars, and required a solution. Removing the overstructure completely was not a viable option. The lack of support would cause the front end of the sled to buckle inwards, colliding with the engine and angling the skis skyward. The support that was required had to be supplied, but in an indirect way.

After a final engine position was decided on, it was possible to start measuring and designing new, modified overstructure supports. This followed the manufacturing of new engine mounts. The overstructure supports currently found in the sled were first designed in creo and analyzed in Ansys, so that it could be determined if this solution was plausible. First a test was run on the stock supports, this was to determine the maximum amount of compressive force they could take. Using this 400 lb compressive force, the test was then run on the newly modeled supports to determine their integrity under pressure. It was concluded that the new overstructure supports experienced proportionately less stress than the stock overstructure, so the team went forward with the manufacturing of the new overstructure design.

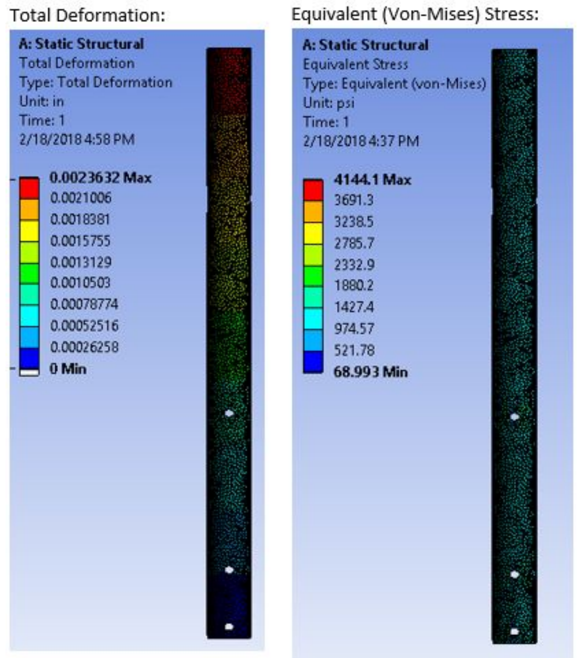

Figure 8: Stock Overstructure

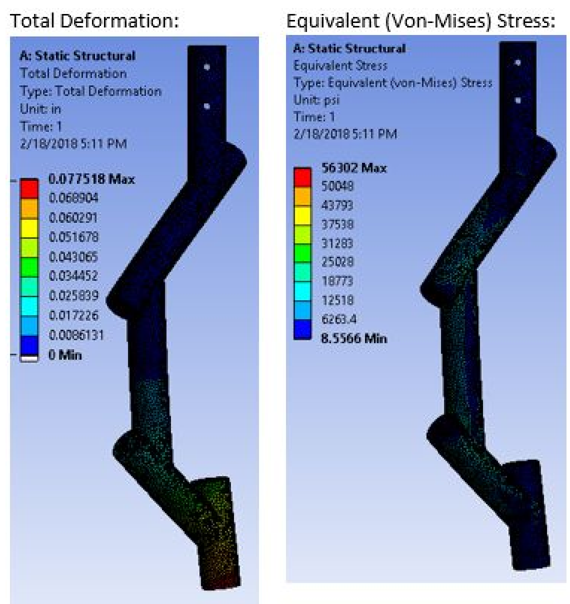

Figure 9: Left Overstructure Support

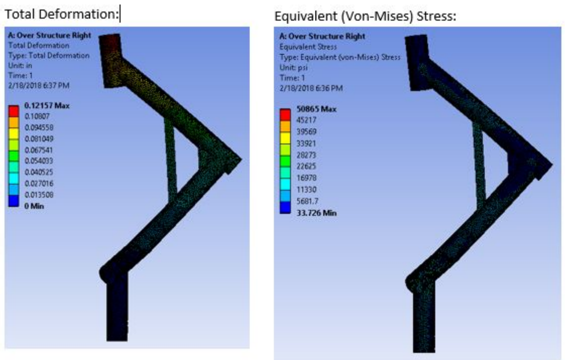

Figure 10: Right Overstructure Support

Drivetrain

Responsible for transferring the power from the engine to the tracks is the drivetrain, a vital system for the sled. Due to diesel engines outputting much higher torque values than IC engines, it was necessary to rework the sleds primary clutch from the ground up. Another reason for this is the change in engine position. Obtaining new clutch components can be quite expensive, luckily the team found a sponsorship with the company Team Industries. Team was able to supply the sled with new modified clutches, optimized for the engine's outputs.

Connecting the engine flywheel to the primary clutch is the stub shaft. With the change in engine position moving it further away from the primary clutch, it was necessary to fabricate a new stub shaft. Using CAD, a new stub shaft was prototyped. Built out of 4140 steel, the new model can withstand the increased torque from the OM660, verified with FEA. The increase in length was a cause of concern for the team, vulnerable to external forces, both radial and axial. To alleviate this risk, a support bearing was placed in the middle of the stub shaft. This bearing is held in place by a bell housing, which is in turn bolted to the engine itself.

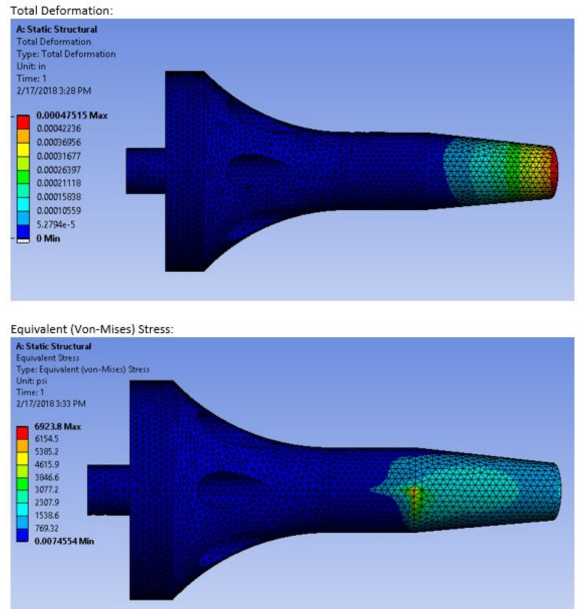

Figure 11: Stub Shaft

Track

For a traction system there were several options to pick from for the NDSU team. When the goal is performance, size is almost always better when it comes to track selection [8]. Studs are also considered to be significant traction improvers, adding performance for icy terrain [9].

The track selected is a Camso Ripsaw track, donated by Camso. 154" in total length, it is 20" wide and features 1.25" lugs. Also acquired and installed on the track are 1.5" long metal studs. The combination of the two provide the system with great traction in all terrain conditions.

Steering System

Another problem caused by the increased engine size inside of the engine bay is the necessary removal of the stock steering shaft that runs down to the skis. The implementation of an alternate steering system was necessary to give the sled user control over the sled's trajectory, while going around the OM660. Unlike the overstructure modifications, it was implausible to bend and modify the steering shaft, as doing so would cause the new shaft to collide with the plastic hood and engine when turned completely to the left or right.

Electrically controlled and powered steering systems were researched. Aftermarket components were out of the teams budget, so development of a custom system was initiated.

After trial runs of electrical motors under various loads, it was found that these motors wouldn't be able to handle the force necessary to turn the skis under external pressure. Hydraulic steering was looked into, but after digging around the team decided there wasn't the necessary time to get this type of steering control working.

The final steering system was chosen after much discussion on the subject. The cable driven steering found in the sled now reflects the dependability of the physically linked rod from the stock sled, while circumventing the OM660 in the engine bay. The overall cost of cable and other components is under $200, a figure that the other two options well exceeded. In addition the cable steering system is small and out of the way, taking up little precious engine bay space.

Conclusion

For this competition, the team has gained significant knowledge about snowmobile design, and about diesel engines. The team designed a snowmobile that will limit its impact on the environment. With the current design, the snowmobile is ensured to produce a decreased amount of pollution, including THC, CO_2, and NOx levels, while still providing high fuel efficiency and little noise.

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Definitions / Abbreviations

DPF	Diesel Particulate Filter
NDSU	North Dakota State University
FEA	Finite Element Analysis
ECU	Engine Control Unit
THC	Hydrocarbons
CO	Carbon Monoxide
NOx	Nitrogen Oxides
CAD	Computer Aided Design