# Clarkson University Diesel Powered Snowmobile

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## Introduction

### *Abstract*

The Clarkson University clean snowmobile team undertook a significant project to utilize a compact diesel engine to power a commercially available snowmobile chassis. The small and powerful Perkins 403D-07 diesel engine was fitted to a 2018 Polaris Switchback SP chassis for use in the 2018 Clean Snowmobile Challenge in Houghton, MI. Several engine alterations were made in response to the limitation of height in the small chassis, of these being a custom build dry sump oil system. Beginning with 13.6 HP at only 2000 RPM, modifications to the fuel and air intake system allowed for a drastic increase in both aspects. Such modifications include the use of a stiffer fuel governor spring, turbocharger and intercooler system. Emissions quality standards are met with the use of a diesel oxidation catalyst, diesel particulate filter and lean fuel/air mixture.

### *Engine Selection*

The selection of a diesel engine was one of the most important undertakings for this year's project. The intended goals of this selection were to match and engine with the expectations of the consumer. This meant that the engine must have superior fuel economy, torque and horsepower output, and maintaining reliability. With the understanding that the greatest obstruction when choosing an engine is size, this immediately resulted in the ruling out any non-turbocharged engines as a naturally aspirated diesel requires displacement to produce power. With this understanding, we initially thought that a 3-cylinder Kohler might be a good choice. However, size and fuel efficiency were also major factors for consideration. This in turn ruled out the Kohler engine option. We concluded that a Perkins 400 series engine was our best option. The Perkins 403D-07 indirect injection 3 cylinder, 760cc mechanically injected was the best platform to build off (similar to the C0.7 on Table 1).

### *Chassis Selection*

For this year's competition we are using a Polaris Switchback SP on the Axys chassis. There are many factors that went into our decision to run this sled this year. The first is the dimensions of the engine bay. With the diesel engine we had to consider a chassis that would allow us to fit the engine and the other customized parts. This is different from the past because we ran the engine that came with the sled so we didn't need to consider engine fitment. The Switchback SP allowed us adequate engine bay height, and width while also giving us room in the front of the sled to attach our exhaust and turbo assemblies. Our other option was a Ski-doo Renegade but the Skidoo did not have the same amount of room as the Polaris. Another factor was cost. The Switchback SP was donated to the Clarkson Snowmobile team by Polaris so this was the cheapest option for us with a limited budget. Another factor is the SP is a crossover sled so it has a longer track (144") then a typical trail sled.

| Category | HP | Size (cc) | Weight (lb.) | MPG | Ease of Clutching | Emissions | Programming | Noise | Mounting | Availability | Total Points | |
|---|---|---|---|---|---|---|---|---|---|---|---|---|
| Importance of Category (1-10) | 7 | 8 | 8 | 5 | 8 | 5 | 8 | 4 | 3 | 9 | 65 | |
| **Motors** | | | | | | | | | | | | |
| C0.5 | 14 | 500 | 126 | N/A | CCW | 3 | ID | 2 | 3 | 8 | | |
| C0.7 | 20 | 760 | 157 | N/A | CCW | 3 | ID | 2 | 3 | 8 | | |
| Kubota | 23 | 902 | 159 | 40 | CCW | 3 | ID | 2 | 3 | 5 | | |
| Yanmar-turbo | 40 | 903 | 242 | 21 | CCW | N/A | ID | N/A | N/A | N/A | | |
| Kohler-turbo | 28 | 1028 | 187 | 31 | CCW | N/A | ID | N/A | N/A | N/A | | |
| Yanmar | 23 | 903 | 242 | N/A | CCW | 4.5 | ID | 3 | 3 | 3 | | |
| Kohler | 23.4 | 1028 | 187 | N/A | CCW | N/A | ID | 4 | 3 | 2 | | |
| **Totals (Scaled 1-8)** | | | | | | | | | | | **Final Score (Out of 65)** | **Ranking** |
| C0.5 | 2.45 | 8 | 8 | N/A | 8 | 3 | 8 | 2 | 3 | 7 | 49.45 | 1st |
| C0.7 | 3.5 | 5.263 | 6.42 | N/A | 8 | 3 | 8 | 2 | 3 | 7 | 46.184 | 2nd |
| Kubota | 4.025 | 4.435 | 6.34 | N/A | 8 | 3 | 8 | 2 | 3 | 5 | 43.799 | 4th |
| Yanmar-turbo | 7 | 4.43 | 4.165 | N/A | 8 | N/A | 8 | N/A | N/A | N/A | 31.595 | N/A |
| Kohler-turbo | 4.9 | 3.891 | 5.39 | N/A | 8 | N/A | 8 | N/A | N/A | N/A | 30.181 | N/A |
| Yanmar | 4.025 | 4.43 | 4.165 | N/A | 8 | 3 | 8 | 3 | 3 | 3 | 40.62 | 5th |
| Kohler | 4.095 | 3.891 | 5.39 | N/A | 8 | 5 | 8 | 4 | 3 | 3 | 44.376 | 3rd |

*Table 1: Engine Comparison for selection*

This is beneficial to us because of the high torque of our diesel engine coupled with the pulling challenges that the SAE Competition requires. Another benefit of the longer track is it allows for the sled to space the gap between bumps on the trails to make for a smoother, more comfortable ride. Also, to improve comfort, efficiency, and handling of the sled we put on new carbide runners, ski protectors, Hiperfax slides, and a 9" diameter big wheel kit. The new carbides ensure the sled can turn sharply and be able to maneuver while the ski protectors make the ride more comfortable and easier on the body as they reduce sled darting. The new slides reduce friction and therefore increase snowmobile efficiency. The bigger wheels reduce the angular acceleration at the rear of the skid due to the increased radius, which in turn reduces the force required to turn the track. The equation for angular acceleration is

$$\propto = \frac{a_t}{r} \tag{1}$$

Force is dependent on acceleration, so the less force required the easier it is for the engine to turn the track, boosting efficiency. All of this factors into making our sled more comfortable, easier to handle, and more efficient for the consumer.

## *Track Selection*

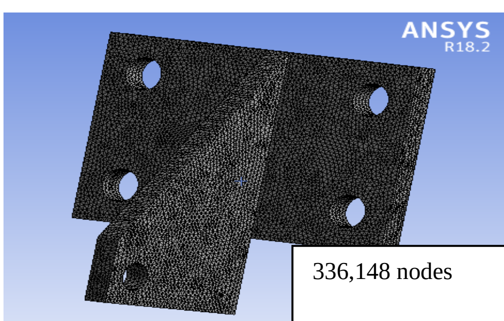
This year we decided to go with a 144" Camso Ripsaw with 1.25" lugs and full 114 Woody's Gold Digger Traction Master 1.325" studs. The sled that we are using this year is a 2018 Polaris Switchback SP. We decided to go with this Ripsaw option due to several reasons. The first reason is the track is a two-ply track so we can safely attach our studs without risk of the track ripping out. Also, the track has a proven track record for traction and durability. Being in the diesel competition we need to have plenty of traction for pulling and acceleration. The deeper 1.25" lug will allow us to accelerate more quickly and without track slippage and the studs will allow us to accelerate even on ice.

# Innovations

## *Analysis of Load-Bearing Fabricated Components*

### Back Right Engine Mount

***Mesh***




336,148 nodes

230,598 elements

Figure 1: Mesh

***Boundary Conditions***

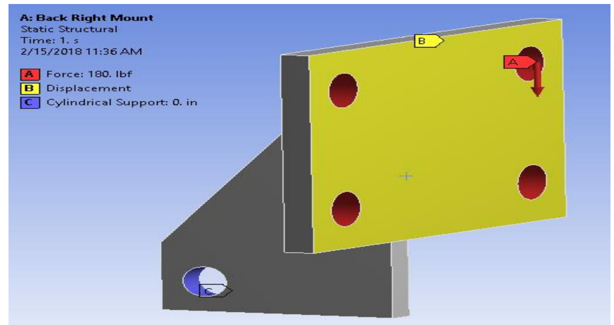



Figure 2: Rendering

On the chassis, this mount is fixed to the factory mounting spot. Due to the fact that there is only one bolt securing the mount, it is possible in an extreme case that if the front mounts sheared off, the engine would just be supported by this mount and the back-left mount. In this extreme case, the engine would slightly rotate down due to the play in the back-left mount. In ANSYS, this is simulated by using a cylindrical support that is free in the tangential direction allowing for possible rotation of the mount. A force of 180 lbf was applied to the four mounting holes to simulate the weight of the engine. This 180 lbf represents the weight of the full engine if in the case all the other mounts fail, the engine could still be supported. By having the engine supported by four mounts, if the mounts were to fail, they would only be able to fail vertically with little to no rotation. This is simulated by using a displacement and fixing 2 directions leaving one free.

***Analysis Results***

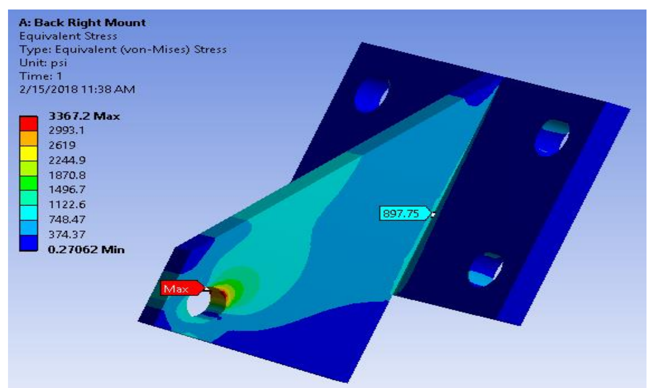



*Figure 3:Stress Analysis*

From the analysis, the max stress on the mount is 3.37 ksi. In an area of concern, where the two plates are welded, the stress is .88 ksi. This mount is made of AISI 1018 Steel, cold drawn. The Ultimate Strength of AISI 1018 is 63.8 ksi and the Yield Strength is 53.7 ksi. The factor of safety equations are on the next page.

$$FS_U = \frac{Ultimate\ Strength}{Working\ Stress}$$

(2)

$$FS_Y = \frac{Yield\ Strength}{Working\ Stress}$$

(3)

From the Analysis data, an Ultimate factor of safety of 18.95 and a Yield factor of safety of 15.95 was calculated.

## Back Left Engine Mount

### *Mesh*

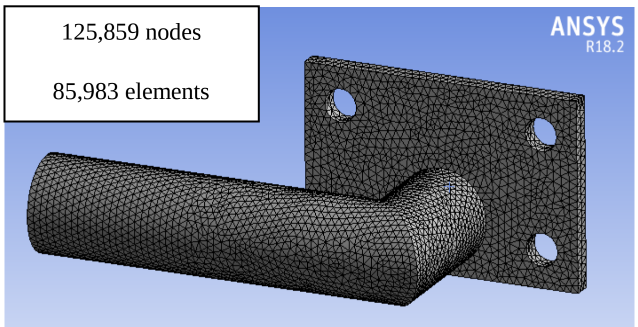



*Figure 4: Mesh*

### *Boundary Conditions*

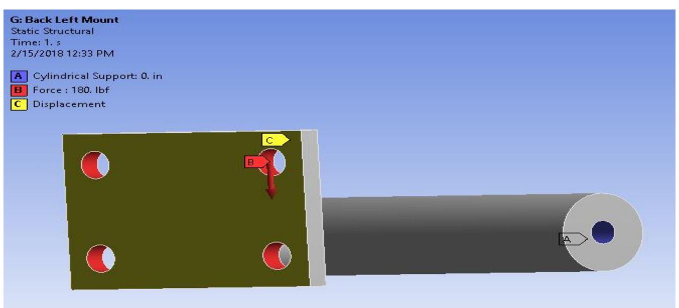



*Figure 5:Rendering*

This mount is secured to the factory mounting dampener. This was simulated using a cylindrical support that was free in the tangential direction. A displacement was put on the face that mates to the block of the engine to simulate the true deformation of the mount. Lastly, a force of 180 lbf was applied to the holes on the mount to simulate the full weight of the engine.

### *Analysis Results*

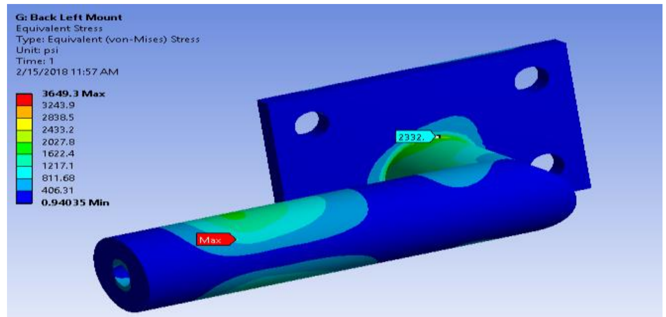



*Figure 6: Stress analysis*

From the analysis, the max stress on the mount is 3.65 ksi. In an area of concern, where the rod is welded to the plate, the stress is 2.33 ksi. This mount is made of AISI 1018 Steel, cold drawn. The Ultimate Strength of AISI 1018 is 63.8 ksi and the Yield Strength is 53.7 ksi. From the Analysis data, an Ultimate factor of safety of 17.48 and a Yield factor of safety of 14.72 was calculated.

## Front Right Engine Mount

### *Mesh*

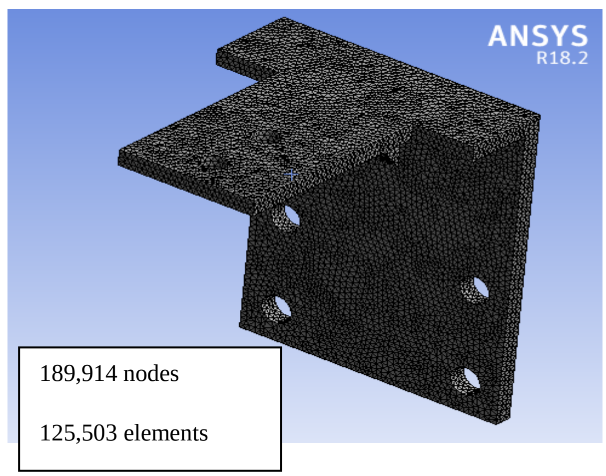



*Figure 7: Mesh*

### Boundary Conditions

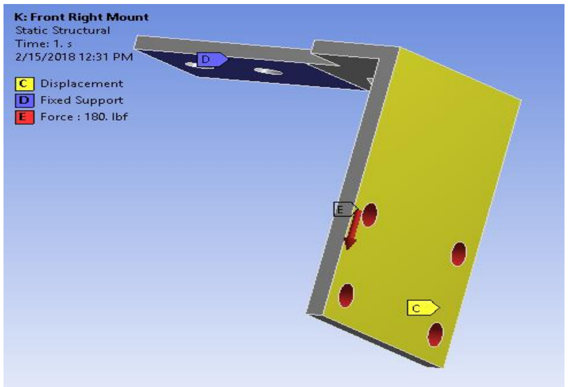



*Figure 8: Rendering*

This mount is secured to a plate that is welded to the front crossover bar on the chassis. To simulate this, a fixed support was applied to the face that mates to the face of the crossover bar plate. A displacement was put on the face that mates to the block of the engine to simulate the true deformation of the mount. Lastly, a force of 180 lbf was applied to the holes on the mount to simulate the full weight of the engine.

### *Analysis Results*

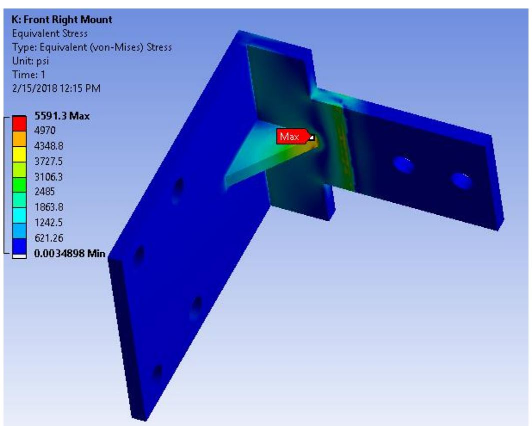
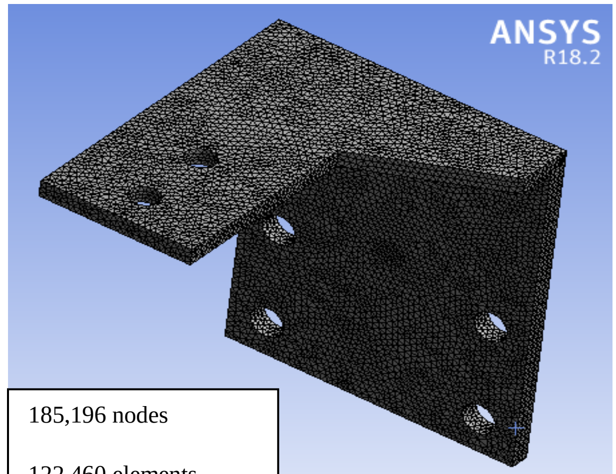



*Figure 9:Stress analysis*

From the analysis, the max stress on the mount is 5.59 ksi. This max stress is on a weld which is an area of concern. To see if this would be allowable, a factor of safety was calculated. This mount is made of AISI 1018 Steel, cold drawn. The Ultimate Strength of AISI 1018 is 63.8 ksi and the Yield Strength is 53.7 ksi. From the Analysis data, an Ultimate factor of safety of 11.41 and a Yield factor of safety of 9.60 was calculated. With factors of safety this high, it can be assumed that the area of concern will not cause failure to the mount.

## Front Left Engine Mount

### *Mesh*




185,196 nodes

122,460 elements

*Figure 10: Mesh*

### *Boundary Conditions*

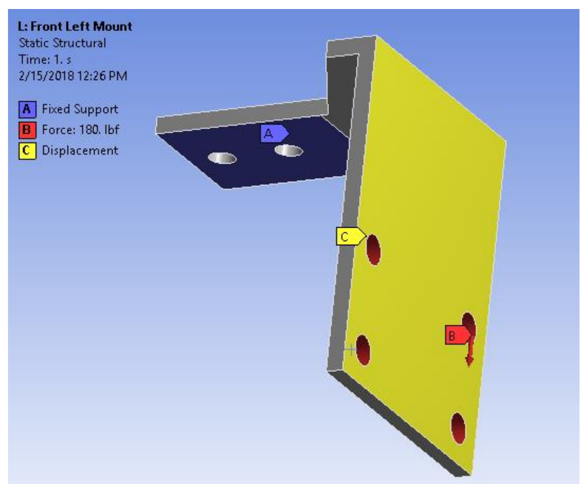



*Figure 11: Rendering*

This mount is secured to a plate that is welded to the front crossover bar on the chassis. To simulate this, a fixed support was applied to the face that mates to the face of the crossover bar plate. A displacement was put on the face that mates to the block of the engine to simulate the true deformation of the mount. Lastly, a force of 180 lbf was applied to the holes on the mount to simulate the full weight of the engine.

*Analysis Results*

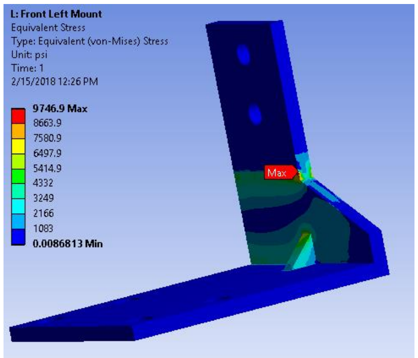



*Figure 12: Stress Analysis*

From the analysis, the max stress on the mount is 9.75 ksi. This mount is made of AISI 1018 Steel, cold drawn. The Ultimate Strength of AISI 1018 is 63.8 ksi and the Yield Strength is 53.7 ksi. From the Analysis data, an Ultimate factor of safety of 6.55 and a Yield factor of safety of 5.51 was calculated.

## Front Crossover Bar

*Mesh*

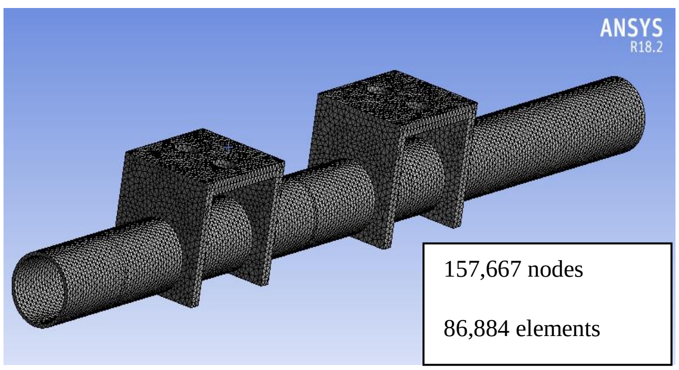



*Figure 13: Mesh*

*Boundary Conditions*

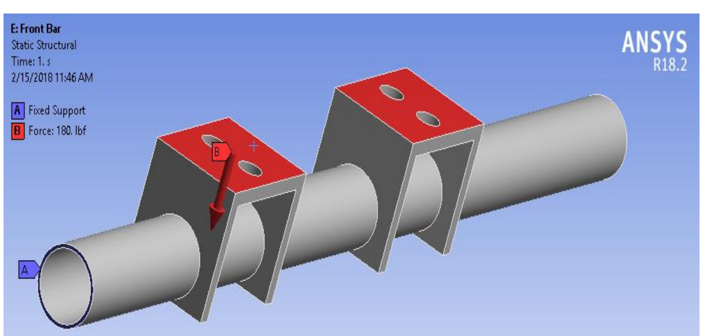



*Figure 14: Rendering*

This is the bar that is in the front of the chassis and is used to strengthen the front of the chassis. Plates were welded to the bar in order to secure the front mounts for the engine. Both ends of the bar are connected to the rest of the chassis. This was simulated by using two fixed supports, one applied at each end. A 180 lbf was applied to both plates to simulate the weight of the engine.

*Analysis Results*

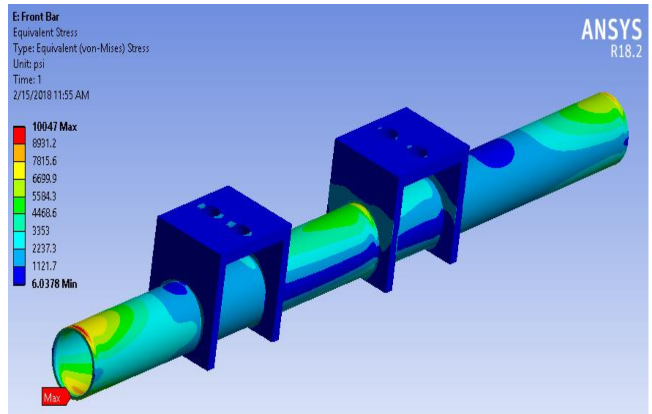



*Figure 15: Stress Analysis*

From the analysis, the max stress on the mount is 10.05 ksi. This mount is made of 6061 Aluminum Alloy per AMS 4026. The Ultimate Strength of 6061 is 30.0 ksi and the Yield Strength is 16.0 ksi. From the Analysis data, an Ultimate factor of safety of 2.99 and a Yield factor of safety of 1.59 was calculated.

## Output Shaft

*Mesh*

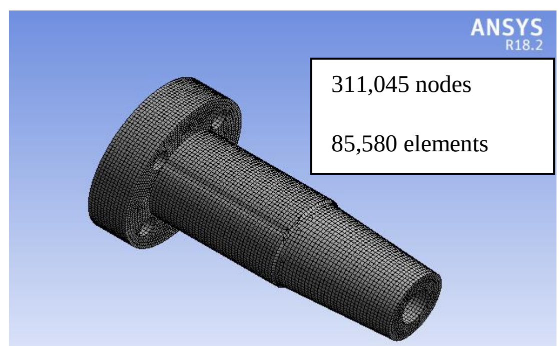



*Figure 16: Mesh*

### *Boundary Conditions*

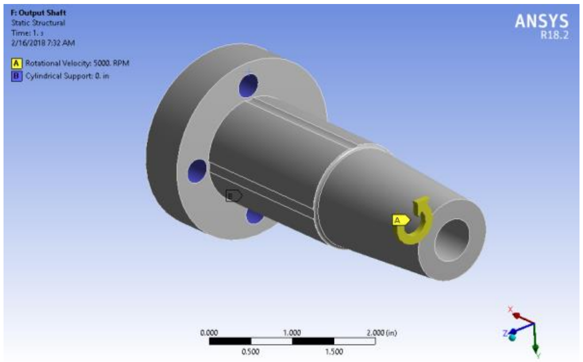



*Figure 17: Rendering*

This is the output shaft that will transfer power from the crankshaft to the clutches. The shaft is fixed in the four holes essentially simulating being fixed by four bolts. Next, a rotational velocity of 5000 RPM was applied to the shaft to simulate the rotation of the shaft when the crankshaft is spinning. A rotational velocity instead of using a force straight down on the shaft was used because it better replicates the real-life operation of the shaft.

### *Analysis Results*

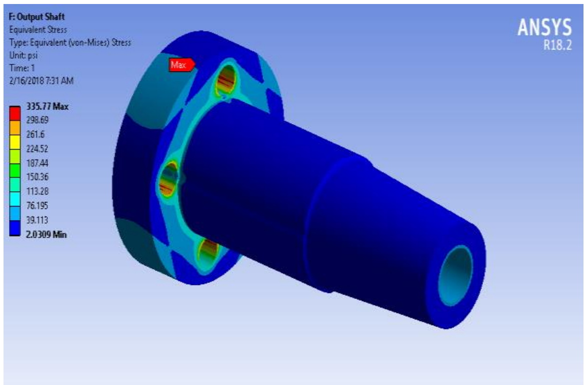



*Figure 18: Stress Analysis*

From the analysis, the max stress on the mount is .34 ksi. The shaft is made of AISI 4340 steel. The Ultimate Strength of 4340 is 161.0 ksi and the Yield Strength is 103.0 ksi. From the Analysis data, an Ultimate factor of safety of 479.49 and a Yield factor of safety of 306.76 was calculated. This stress on the shaft also represents the stress that will be applied to the bolts. Since the max stress is only .34 ksi, it is assumed that our hardened bolts will not shear.

## *Turbocharger*

Due to the fact that our engine only has 27.3 hp at 3400 RPM it was necessary for us to include a turbocharger in our design. To find out which turbocharger best suited us, we figured out what horsepower we wanted to attain. First, we figured out what goal hp we wanted to achieve; these goal hp are 30hp, 35 hp and a max of 40 hp. Next, we used formulas provided by Honeywell to find our Corrected Air Flow in lbs. /min and our Pressure Ratio for each targeted horsepower. We then took these values and plotted them on compressor maps from Honeywell. First, we plotted points on the GT0632SZ compressor map; this map is shown below.

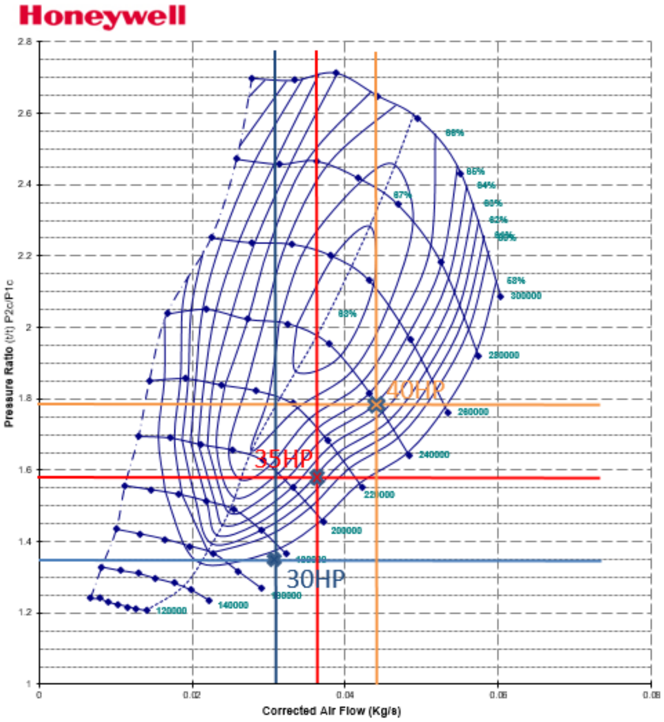



Figure 19: GT06 Turbo Efficiency

### *Plot Summary*

At 30 hp, the plot is off the grid, at 35 hp the turbocharger will be 62% efficient, and at 40 hp the turbo charger will be 66% efficient.

Next, we plotted points on the GT1238Z compressor map; this map is shown on the next page.

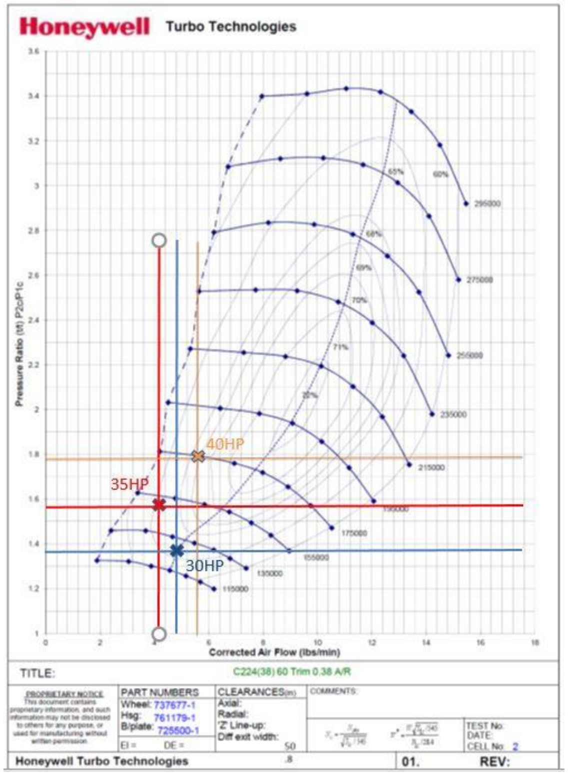



*Figure 20: GT12Z Turbo Efficiency*

***Plot Summary***

At 30 hp and 35 hp the turbocharger will be 65% efficient, and at 40 hp the turbocharger will be 68% efficient.

### Turbocharger Summary

Our initial thought was that a smaller turbo like the GT0632SZ would be better suited for our engine but through data analysis, we figured out that the larger GT1238Z would be the best fit for our engine. This data shows that the GT1238Z is more efficient through the range of targeted power than GT0632SZ. In order for an optimal match, we decided to use the GT1238Z due to its superior efficiency at our target power range.

### Intake

In order for the turbo to draw as much air flow as it needs to properly compress the air in the intake, the appropriate area of K&N filter was required. This was calculated using the following equation:

$$A_f = \frac{lbs\ boost}{14.7} + \frac{1 * CID * \max RPM}{20839}$$

(4)

In equation 4, $A_f$ is the area of K&N filter and CID is displacement in cubic inches. Using this equation with a targeted boost of 10 lb, the required area of K&N filter is 8.69 cubic inches. With this in mind, we were able to purchase a K&N filter that would be small enough to fit in the front of the engine bay and still provide enough air flow for the turbo. Furthermore, to help with sound dampening from the intake, we had a new airbox 3D printed.

### Intercooler

In order to achieve maximum efficiency with our GT1238Z turbocharger, we decided to incorporate an intercooler into our design. The intercooler was designed by Bell Intercoolers and its purpose is to cool the air coming from the turbocharger before it reaches the intake of the engine. This is necessary because as the air is compressed it generates heat from friction that raises the temperature of the intake air. According to the ideal gas law:

$$P = \rho RT$$

(5)

This shows that at constant pressure (since the turbo can only produce so much boost), an increase in temperature will directly cause a decrease in the density of the air entering the engine. This will lower the air-to-fuel ratio (AFR) reading, despite having a constant volume of air, due to less mass per unit volume. As a result, less fuel will burn causing a decrease in power output and an increase in soot production. The intercooler therefore enables greater turbocharger effectiveness.

Due to the climate that snowmobiles operate in, an air to water intercooler is not necessary. Therefore, we decided to utilize an air to air intercooler. By choosing this design we will rely on the cold winter air to cool the charged air. Lastly, the price of an air to air intercooler is significantly cheaper and less complex than an air to water intercooler resulting in a more affordable end product for the consumer.

## *Emissions*

The main component of the emissions system is an oversized diesel emissions component designed for a 2.5L Volvo C30, V40, and XC90. The system features a diesel oxidation catalyst (DOC) for oxidizing nitrous oxides ($NO_x$), hydrocarbons (HC), and carbon monoxide (CO), as well as a diesel particulate filter (DPF) designed to catch and trap soot particulates until the regularly occurring active regeneration phase. The main factor affecting both items is a diesel injection port that enables the higher exhaust temperatures required for soot oxidation and improved oxidation efficiency.

### Diesel Oxidation Catalyst

The first component for emissions reduction is the diesel oxidation catalyst. For the diesel emissions application, the DOC is lined with alumina, rare earth oxides, zeolites, and precious metals to aid in the conversion of harmful gases to neutral entities. Alumina provides a large surface area per unit volume for the other oxidizers to occupy, increasing the likelihood of oxidation for the harmful gases. Rare earth oxides, zeolites, and precious metals then line the surface area provided by the alumina and act as the oxidizing agents in the oxidation of harmful gases. However, this oxidation is not uniform with temperature. Shown in Figure 21 below is the efficiency of the DOC throughout a range of temperatures. Notice how there is almost no conversion at low temperatures:

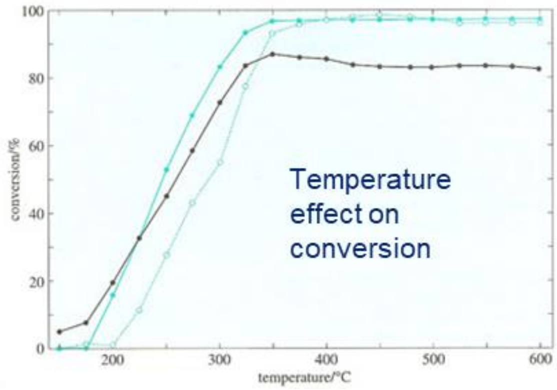



*Figure 21: Conversion Percentage vs Temperature for $NO_x$, HC, and CO*

According to the graph shown in Figure 21, design in regards to temperature will have a major impact on the efficiency of the system. Ideally, the DOC should be located as close to the engine as possible to prevent heat loss through the exhaust system, however space restraints forced us to locate it downstream from the turbocharger. In addition, the volume of the DOC relative to the size of the 760cc engine will take a longer period of time to heat up the DOC to a point where it can even begin oxidizing the harmful pollutants. To decrease the time to fully heat up the DOC, the entire exhaust system was wrapped with titanium heat wrap to hold the necessary heat in and shield vulnerable components nearby. In addition, both to decrease the time to heat up the DOC and to raise the exhaust temperature to new levels, an injection port is located upstream from the DOC and DPF to inject diesel fuel directly into the exhaust system. The diesel fuel reacts with unburned HC under high heat to release high levels of energy into the system. This is beneficial to both the DOC and DPF.

### Diesel Particulate Filter

Downstream from the DOC and directly connected is the DPF. The system inside the DPF provides a large surface area for soot to collect, which approaches 99% efficiency once the initial soot begins to collect. This collection will continue to occur until either the system clogs or the active regeneration phase occurs. This phase is initiated by the introduction of diesel fuel into the exhaust system directly above the DOC. The additional heat from the reaction of the fuel in the exhaust allows temperatures to become so hot that the unburned soot particles will oxidize and turn to ash, then releasing into the atmosphere in an eco-friendlier form. The exact makeup of the DPF is unknown due to information that the company was willing to give out, but is likely made of Silicon monocarbon (SiC) or titanium aluminum alloy (TiAl). These compounds have the ideal thermal gradients to handle the excessive exhaust temperatures that they will be exposed to.

The DPF can be controlled by the use of pressure sensors. As the system fills with soot, the backpressure will increase as well as the difference in pressure readings between the pressure sensor at the beginning and end of the DPF. It is important to regulate this backpressure to prevent a decrease in efficiency from the turbo that would throw off engine fuel mapping and cause the system to run more rich (same amount of fuel injected at a lower pressure would mean less oxygen for combustion), causing an increase in soot production. This is the Achilles' heel of our design. Since our engine is mechanically run, we did not acquire a programmable engine control unit (ECU) that could read a difference in pressure and regulate the active regeneration phase. As a result, our options were to include a switch to manually control the active regeneration phase, which is not ideal and highly inefficient, or to run the part without regeneration, which risks total system clogging and part failure. Looking into the second year of this project, our main goal will be programming an ECU to properly regulate the diesel exhaust injection [1].

## *Engine Modifications*

| | |
|---|---|
| Engine | Perkins 403D-07 |
| Displaced Volume | 760cc |
| Stroke | 72.0 mm |
| Bore | 67.0 mm |
| Compression Ratio | 23.5:1 |
| Number of Cylinders | 3 |
| Cycle | 4 stroke |
| Combustion System | Indirect Injection |

*Table 2: Engine specifications*

### Governor Spring

The engine that was purchased for this year's project was an 1800 RPM generator model. In order to compete with acceptable performance, a drastic increase in speed was paramount for our success.

The governor spring in the engine controls the fueling, and therefore speed. Theoretically, a stiffer spring will pull the fuel lever further, thus increasing the RPM's. Experimentation with several springs allowed an increase from 2000 RPM max, to 3756 RPM max. The results from this change can be seen in the dynamometer results in Figure 22 below.

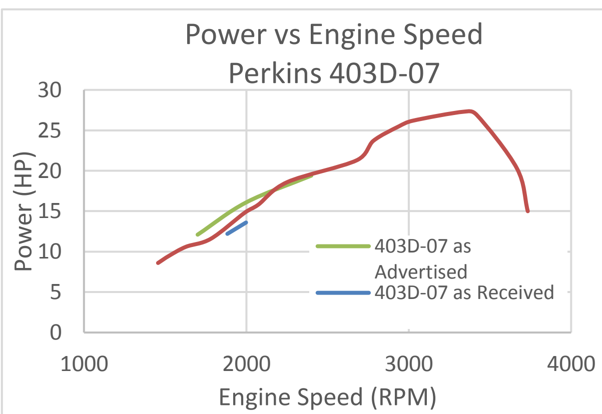



*Figure 22. Dynamometer results from stiffer governor spring*

## Dry Sump Oil System

The fitment of the larger diesel engine in the Polaris chassis was difficult, and limited in the vertical direction. To simplest way to shorten the height of our engine was a decrease in oil pan dimension. A 2" center section of the steel oil pan was cut and removed, then re-welded together. The reduction in height from 4" to 2" gave the team enough space to comfortably mount the engine in the chassis.

The original oil pan housed enough space for 0.8 US Gallons, the recommended oil capacity. However, this reduction in height did not allow for that capacity. The use of a dry sump oil system was the best answer to our problem, and would allow for the amount of oil that would be needed to safety lubricate our engine and turbocharger. A block diagram of the operation of our dry sump system is shown below in Figure 23.

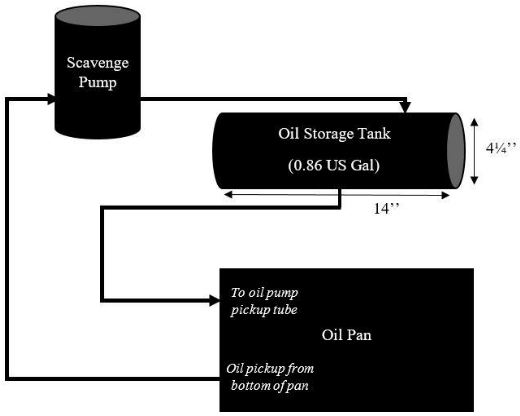



*Figure 23. Dry sump oil system block diagram to show the flow of oil from engine oil pan, to the oil storage tank, then returned to the engine oil pump.*

The tank design was based on physical constraint to size and shape on the chassis as well as oil capacity needed. A volume of 0.86 US Gal of oil was determined to be the need, as well as a tank no more than 14" in length for chassis fitment. The tank was built as close to needed specifications, and the final product is shown below in Figure 24.

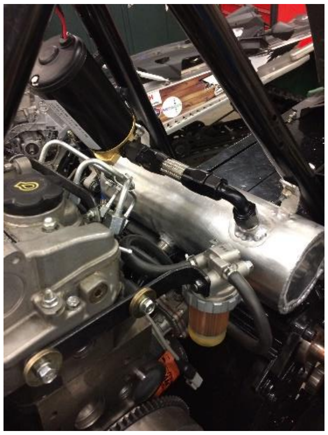


*Figure 24. Custom built oil storage tank to fit within limits of the small chassis, maintaining lubricating capacity.*

The use of a scavenge pump was needed to constantly pull oil from the pan, to an elevated level for storage in the tank. The CXRacing electric scavenge pump was chosen based on it fast 3.7 GPM rating, solely electrical supply reliance and its relatively low weight compared to similar pumps in its class.

### *Clutching*

Diesel engines have a significantly lower RPM range than that of a 2-stroke engine. Due to this, a new clutching system had to be used. We worked closely with TEAM Industries Inc., a company whom specializes in continuously variable transmissions in order to conclude a setup that would work with the Perkins 403D-07 engine. We determined that a lower spring constant and heavier weights were needed in the primary clutch in order to accommodate for the lower RPM range. The lighter spring constant allows for quicker engagement and the heavier weights create more rotating mass which decreases the rotational speed of the primary clutch. The mass of the weights were determined using the following equation:

$$F = MRV^2 \tag{5}$$

Where F is the centrifugal force acting on the weights, M is mass of the weights, R is radius from the center most point of the primary clutch to the centroid of the flyweight, and V is the velocity, which can be determined by RPM.

## Team Organization and Time Management

The team's organizational structure was decided by voting. We set up a team meeting and first had people nominate for different positions and then we all cast an anonymous vote. The team's leaders are Austin Donhauser and Billy Windsor as co-presidents, Shawn Schneider as team secretary/business man, and Ryan Phillips as safety representative. We then divided the project into smaller projects/categories with a given sub-team leader for each. Austin Donhauser is engine/turbo sub-team leader, Shawn Schneider is emissions sub-team leader, Clayton Lyon is track and skid sub-team leader, Keenan Lynch is Clutching sub-team leader, and Josh Wyant is fabrication sub-team leader.

To ensure we stayed on track during the year we first set long term, roughly set dates on when we wanted larger projects to be completed. Then every week the co-presidents and team leaders set a list of projects that needed to be worked on/completed for the week to ensure we stayed on track long term and continued to progress. As a team we divided and conquered on different duties in order to make sure all smaller projects would get completed in any given week. A Gantt chart (Figure 25) of our goals is on the next page.

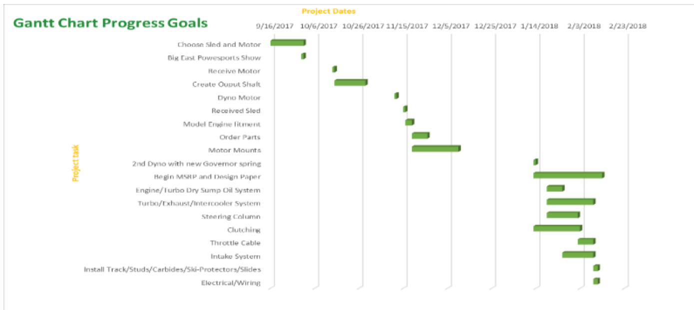



*Figure 25: Project Progress*

## Summary and Conclusions

### *Summary of Main Components*

- Chassis – 2018 Polaris Switchback 600 SP
- Engine – Perkins 403D-07, 4-stroke diesel, 760cc, peak horsepower: 27.3 (measured by Clarkson University using a Land & Sea Dynomometer)
- Track – Camso, Ripsaw 144"x15"x1.25" (length, width, lug height), 2.52" pitch, 2-ply, Woody's Gold Digger Traction Master studs, 1.325" height
- Skid – Stock with exception of: TKI Offset 2 Wheel Axle Kit with 9" Composite Big Wheels, Hiperfax Slide Rails
- Intercooler – Custom Bell Intercooler with SPAL Fan.
- Skis – Stock with exception of: Woody's Trail Blazer IV Flat-Top Carbide runners, Woody's Navigator Ski Protectors
- Turbo – Garrett GT1238Z
- Custom Fabricated Dry Sump Oil System
- Battery – Shorai Xtreme-Rate 12-Volt LifePo4 LFX Lithium Battery
- Clutch – Customized TEAM Clutch
- Exhaust – Faurecia Emissions Control DPF
- Intake – K&N conical air filter

## Discussion

Overall, our goal was to design a snowmobile that would be clean, quiet, and fuel efficient but also still be able to be a reliable utility sled for the consumer. To achieve this, we decided to add a turbocharger to our design. By integrating a turbocharger, the added air will clean out our emissions resulting in an overall cleaner and more efficient snowmobile. Our next step for better emissions was to add a diesel particulate filter and diesel oxidation catalyst. The theory behind adding a DOC is that it will convert most of the diesel exhaust into harmless substance such as carbon dioxide and water. Next, the theory behind adding a DPF is that it will burn off the soot that the motor creates resulting in better emissions. The DOC and DPF will also act as a muffler due to the filters inside the DOC and DPF housings. These filters muffle the noise of the engine resulting in a quieter snowmobile. Lastly, we decided to use the Polaris Switchback chassis instead of a traditional utility chassis. Our thought behind this was that the Switchback chassis is lighter than a utility chassis which in turn would result in greater efficiency.

## References

1. Hijazi, Claudinei. Personal Communication. 10 February 2018.

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- Faurecia
- Garrett by Honeywell
- Ingles Performance
- Klim Technical Riding Gear
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- NYSSA
- Polaris
- Ricardo
- Snap-On Tools
- SolidWorks
- TEAM Industries
- Windsor Landscaping
- Woody's

Without them, this project would not have been possible.

## Definitions/Abbreviations

| | |
|---|---|
| **AFR** | Air-to-fuel ratio |
| **CO** | Carbon Monoxide |
| **DOC** | Diesel oxidation catalyst |
| **DPF** | Diesel particulate filter |
| **ECU** | Engine Control Unit |
| **HC** | Hydrocarbons |
| **$NO_x$** | Nitrous Oxides |
| **RPM** | Revolutions Per Minute |
| **SiC** | Silicon Monocarbon |
| **TiAl** | Titanium Aluminum alloy |