2010-24-Feb

Design of a Turbocharged Four Stroke Snowmobile With Low Exhaust and Sound Emissions

North Dakota State University: Team 13

Michael Fegley
Team Captain

Keith Leier
Public Relations

Steve Schmidt
Lead Design

ABSTRACT

The 2010 SAE International Clean Snowmobile Challenge will be North Dakota State University's first competition. After falling just short in 2009, NDSU's 2010 CSC Team is looking to improve upon the previous designs and experiences of former team members and finally make an appearance at this year's event. Using the same simple yet efficient design approach mindset as year's past, this year's team again looks to produce a more fuel efficient, quieter and cleaner product while making minimal changes to the production techniques of the original stock snowmobile.

INTRODUCTION

Snow sports have always been a large part of the United States' Upper Midwest recreational activities and the quest for new and exciting adventures is always on the minds of avid enthusiasts. This exploratory mindset is leading today's snowmobilers to the Nation's most pristine and wild areas and is making the United States' National Parks and Forests prime real estate. Because of the growing interest in these remote areas, along with the need to keep them as preserved as possible, efforts between snowmobile manufacturers and park officials should be made to help provide a fun and exciting experience for snowmobilers while keeping intact the integrity and beauty of one of our Nation's most valuable resources.

The design approach of North Dakota State University's 2010 CSC Team is to produce efficient and effective solutions to help reduce the environmental impact of production snowmobiles. Using a 2008 Polaris FST Dragon IQ chassis and a Weber 750 turbo-charged motor from a '06 Polaris FST Switchback, the design team looks to develop new systems which can be implemented to a stock Polaris snowmobile, reducing noise, emissions, and increasing fuel economy, while still allowing for an efficient, reasonable and cost effective production product.

EXHAUST

The design of the exhaust system is the most critical aspect in the goal of reducing emissions. To address this issue, NDSU's CSC Team designed a portion of the stock exhaust with the inclusion of a Catalytic Converter. The catalytic converter tested is a Magnaflow 50000 Series Catalytic Converter Pre-Converter. This product was chosen for its compact design and its high temperature resistance [2]. Both stipulations were necessary due to its close proximity to the turbo charger (see picture below, *Figure 01: Modified Exhaust with Catalytic Converter*).

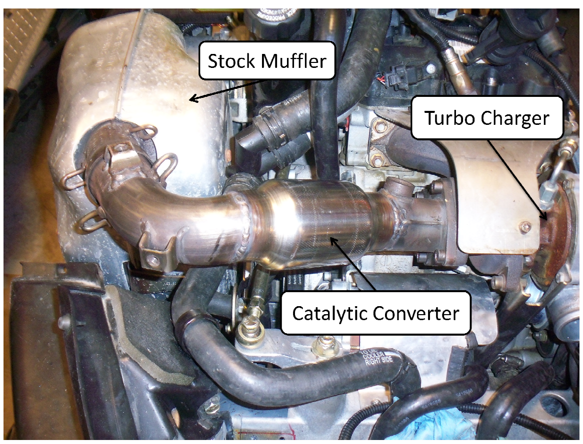


Figure 01: Modified Exhaust with Catalytic Convert

Emission testing was performed on both stock and modified exhaust components via DYNO-mite Dynamometer and NOVA Gas Analyzer testing equipment. Comparisons between stock and modified components were made and the following results were obtained: %CO_2 was decreased by 60.31%, HC's (PPM) were decreased by 100%, NO_2 (PPM) decreased by 52.98%. The results shown are averages across the middle three testing modes as these account for the normal operating range of the motor and are the heaviest weighted modes for competition scoring (See attached Graphs 01, 02, and 03 in Appendix A, for further detail) [1].

Figure 02: DYNO-mite Dynamometer and Emission Level Testing

Other areas addressed in the exhaust design modifications dealt with power loss experienced by the motor. To account for this effect a high flow catalyst was a design characteristic needed for the implemented catalytic converter. To test the performance effects on the snowmobile's motor, DYNO-mite Dynamometer testing was again preformed. It was determined that the implementation of the catalyst in the stock exhaust system resulted in a 10.13% power loss, leaving the modified exhaust snowmobile power at 105.6 hp (see Appendix A, *Stock and Modified power curves*).

FUEL SYSTEM

For the 2010 Clean Snowmobile Challenge an E20-E29 ethanol gasoline blend is supplied to each snowmobile team during competition. This meant that each snowmobile had to automatically adjust for the different blend levels on the fly.

In order to run the mix of ethanol and gas the snowmobile's fuel system had to be able to withstand the corrosive properties of ethanol. This resulted in all fuel lines and fittings being changed to an ethanol compatible component. Northern Engine in Fargo, ND was consulted in the selection of fuel lines and fittings.

After much research was conducted it was concluded that the Bosch Closed Loop Fuel System had enough adjustability in itself to allow the engine to run on different fuels. The snowmobile is outfitted with an oxygen sensor that constantly monitors the AFR and adjusts fuel injector pulse width times in an effort to adjust the AFR value. It is also outfitted with a knock sensor that can tell if the timing of the engine is even slightly off. When ethanol is put into the snowmobile tank it is believed that the AFR value is low and the engine timing is off the ECU recognizes this and adjusts accordingly.

Although the ECU can adjust the timing and the pulse width the stock fuel system is still not capable of filling the cylinders with fuel fast enough to account for the energy differences between ethanol and gasoline. This resulted in the purchasing of two components to make up for this, a high performance in-line electric fuel pump and a fuel pressure regulator (see *Figure 03: Fuel System Design*) [4].

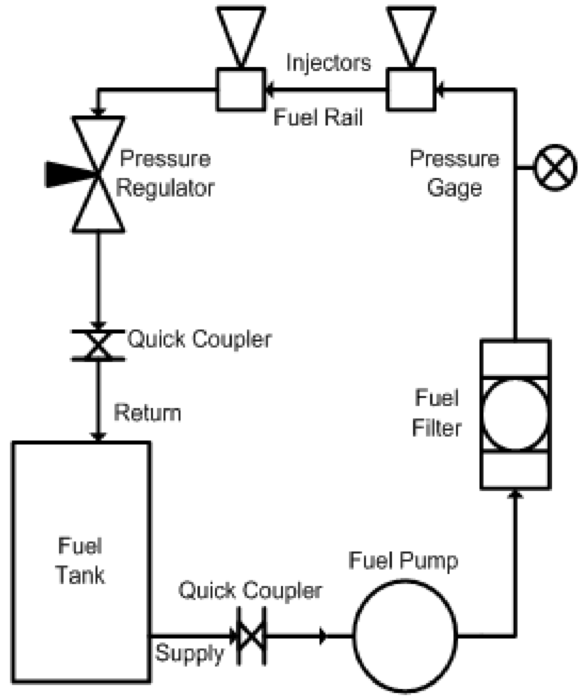


Figure 03: Fuel System Design

The stock fuel pump was an in-line model that was located in the gas tank. This fuel pump was not ethanol compatible resulting in need for a replacement. In addition to the ethanol compatibility issue the competition requires the use of an external in-line fuel pump for the emissions event. The team began to examine various models and eventually chose an Edelbrock Street/Strip Electric Fuel Pump 3594. This pump is capable of producing 57 gallons per hour (gph) of flow and is also alcohol compatible. Alcohol compatibility ensures ethanol compatibility [3].

Stock fuel pressure for the Polaris FST is 42.5 psi roughly. In order to run on ethanol the engine must be fed more fuel as previously stated. In order to adjust working fuel pressure a fuel pressure regulator is needed. Again much research was conducted and an Edelbrock Fuel Pressure Regulator PN:1728 was chosen.

Testing was performed with various fuel mixtures ranging from standard E10 90 octane pump gasoline to an E30 mixture of E10 and E85. The tests were performed both during normal riding conditions as well as high load dynamometer tests. With the ability to adjust fuel pressure in our system we were able to obtain an optimum fuel pressure of 50psi. This pressure was selected because of the well rounded performance it produced with E20 to E29 fuel mixtures.

NOISE REDUCTION

With the increase in noise stipulations in forests and parks, snowmobile designers are more concerned than ever about producing quiet snowmobiles. The goal of the NDSU Clean Snowmobile Team is to reduce sound emission on the 2008 Polaris IQ Turbo Dragon to equal or fall below that of a 2006 Polaris FS Classic.

The largest contributors to sound emission on the competition snowmobile were found to be at the drive wheels, chain case, clutches, exhaust exit and the engine.

To reduce sound emission from the drive wheels a spray-on bed liner material was installed in the tunnel. This material was followed by a layer of high density foam and an additional layer of spray-on bed liner over the foam. These materials will change the resonating frequency by adding stiffness to the tunnel. The absorbed sound energy is converted into tiny amounts of heat.

The sound emission from the chain case, clutches, and the engine were reduced by the addition of JEG's Quiet Ride material installed on all the panels surrounding the engine compartment.

To reduce exhaust gas sound emission along with reduce emissions a MagnaFlow 50000 Series catalyst was installed after the turbocharger and before the muffler.

In field sound testing was performed using a calibrated sound meter (Extech Instruments Model 407788). Tests were performed at a steady state 15mph drive by along with a 15mph-30mph accelerated run. The control snowmobile for the experiment was a stock 2006 FS Classic. The FS Classic also has the Weber MPE 750 engine with plastics identical to the 2008 Dragon. These similarities made for an excellent direct comparison in sound emissions. The testing route was a 150ft start to finish lane with the microphone positioned 50ft from the middle of the testing route at a height of 4ft. The sound meter gave a maximum decibel reading from each drive-by. Drive-by readings were taken from both the left and right side of each snowmobile.

Our maximum decibel readings concluded that a considerable reduction in sound emission was seen on the 2008 Dragon. The Dragon's average reading on the 15mph steady state was 69.67dB on the left side and 69.89dB on the right. This is a 7.3% decrease on the left and a 6.8% decrease on the right. In the acceleration from 15-30mph a decrease of 2.1% was seen on the left and a 1.7% decrease on the right. The reason for less improvement on the 15-30mph acceleration is most likely due to the turbocharger spooling noise. See Appendix A, for direct comparison graphs of the sound testing.

REQUIRED COMPETITION MODIFICATIONS

RE: ARTICLE 4

The rules and regulations of the Clean Snowmobile Challenge state that each snowmobile must meet minimum safety requirements to be eligible for competition. The team snowmobile did not meet many of the regulations in stock form. Each modification performed on the sled is described in detail below [1].

CLUTCH COVER: CSC RULE (4.4.7)

The clutch cover serves two purposes: It forms a barrier between the moving components of the primary and secondary clutches under normal operation, and it also provides safety from any debris that could be propelled by the clutches in the event of belt failure. The cover is a two - piece configuration that is fastened to the engine mounting plate and the firewall. It is constructed of T 6061 aluminum covered with nylon-rubber composite belting to contain projectiles if the aluminum is compromised. A picture of the finished clutch cover incorporated onto the competition chassis can be seen in Figure 04 below.

Figure 04: Clutch Cover

SNOW FLAP: CSC RULE (4.7.1)

The purpose of the snow flap is to block any ice/snow or other debris that could be propelled by the track. The snow flap is comprised of nylon-rubber composite belting mounted to the back of the tunnel. The width of the snow flap exceeds the width of the tunnel by 1 inch, which is required by the rules of the 2010 competition.

FRONT BUMPER: CSC RULE (4.7.6)

The stock bumper on the competition sled was not capable of supporting the full weight of the snowmobile while suspended in the air. To comply with the rules an aftermarket bumper was purchased and modified to accommodate the engine cooling components on the snowmobile.

The aluminum aftermarket bumper was designed for Polaris snowmobiles without the lower radiator; however the competition sled is so equipped. This caused the upper and lower bumper supports to interfere with the mounting position of the radiator. The decision was made to remove the upper supports completely and shift the radiator position upward to allow the lower supports to fasten to their intended mounting position.

The upper supports were designed to allow adequate clearance for the radiator without sacrificing structural integrity or compromising any other necessary equipment in the engine compartment. The upper supports join the lower supports to the bulkhead just below the stock intercooler. The bumper is constructed from T6061 aluminum and is fastened to the snowmobile by bolts and steel rivets for ease of installation.

The redesigned bumper was easily installed on the snowmobile with minor modifications to the belly pan and side panels to allow for clearance between the bumper supports and the plastic body components in the engine bay. The redesigned front bumper can be below with all necessary cooling systems functioning and in place.

Figure 05: Installed Competition Clutch Cover

BATTERY BOX: CSC RULE (4.8.5)

The battery enclosure must be constructed of non-conductive material and sealed from the outside environment with a vent. The purpose of this requirement is to ensure that the fluids in the battery do not come into contact with other components of the snowmobile in the event of failure. A picture of the battery box can be seen above in the next column.

Figure 06: Sealed battery Box

The enclosure was constructed using a combination of woven and non- woven fiberglass matting with high strength resin to bond the materials. The design consists of a two-piece format, a lower cradle to securely hold the battery and a lid to form a completely sealed and vented structure. With slight modifications to the stock battery box, the fiberglass enclosure was easily implemented onto the chassis.

SUMMARY/CONCLUSIONS

Upon completion of the Clean Snowmobile Challenge Competition preparation, the NDSU CSC Team's design concepts were justified by significant reductions in emissions and noise levels; both being accomplished without large sacrifices to the integrity of the sport or snowmobile itself. Fuels system adaptations for flex fuel mixtures were made and all necessary competition safety modifications were met at levels above and beyond the minimal requirements of the competition.

North Dakota State University's Clean Snowmobile Challenge Design resulted in meeting the team's set forth goals: A cleaner, more quiet snowmobile was able to be developed, and it was achieved by an efficient, effective and production friendly design process.

REFERENCES

1. *2010 SAE Clean Snowmobile Challenge Rules. SAE International.*
2. *JEGS Automotive Parts. < http://www.jegs.com/.>*
3. *Fuel Pump and Fuel Pressure Regulator <http://www.edelbrock.com/automotive_new/mc/fuel_pumps/fuel_pumps_main.shtml.>*
4. *2006 Polaris FST Classic Service Manual. Polaris Industries.*

CONTACT INFORMATION

Michael Fegley
michael.fegley@ndsu.edu

Keith Leier
keith.leier.1@ndsu.edu

Steve Schmidt
steven.j.scmidt@ndsu.edu

ACKNOWLEDGMENTS

Special Thanks to:

North Dakota State University Dept. of Mechanical Engineering and Applied Sciences

North Dakota State University Student Government

North Dakota State University Society of Automotive Engineers

Polaris Industries

North Dakota Corn Growers

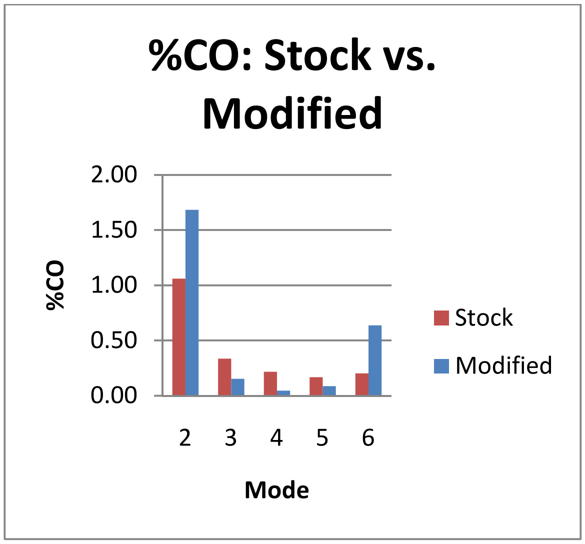
Xcel Energy

Emitec Innovations

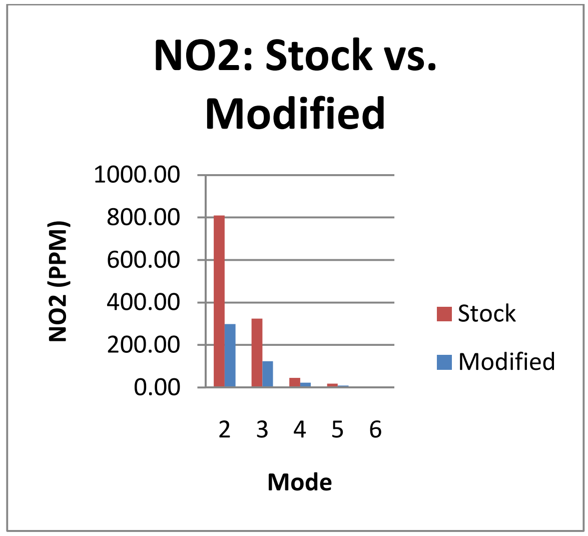
APPENDIX A

CHART

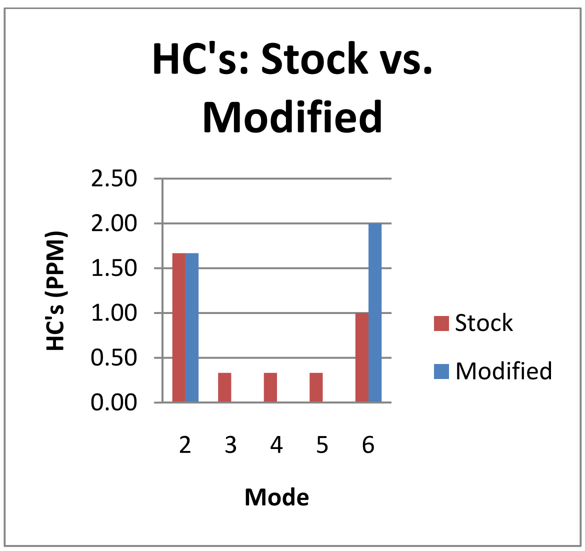
EMISSIONS



Emissions 01: %CO: Stock vs. Modified Exhaust

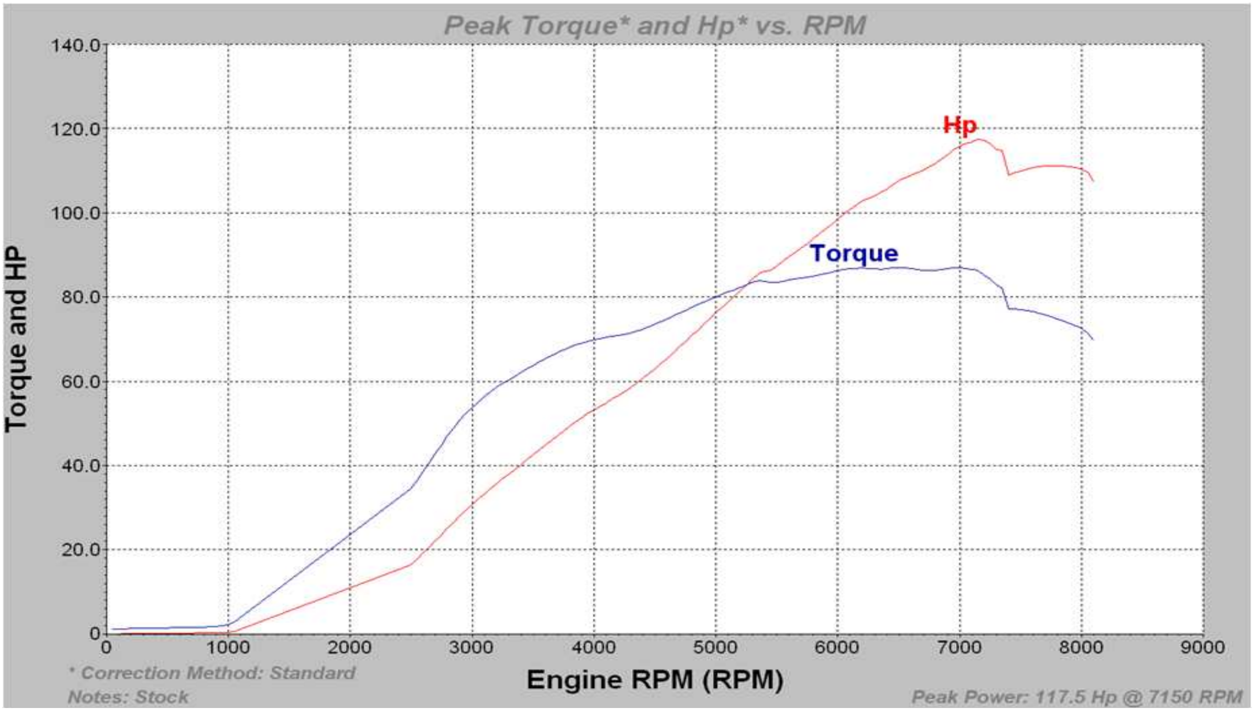


Emissions 03: NO2: Stock vs. Modified Exhaust

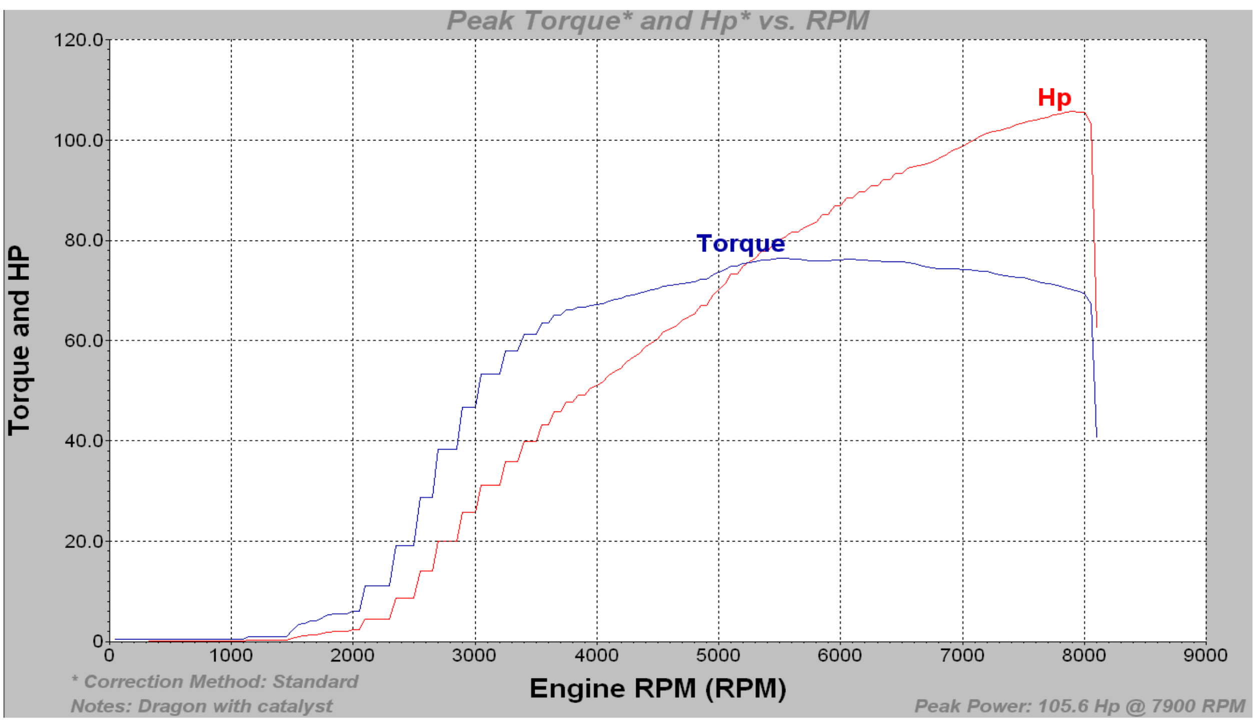


Emissions 02: HC's: Stock vs. Modified Exhaust

POWER CURVES

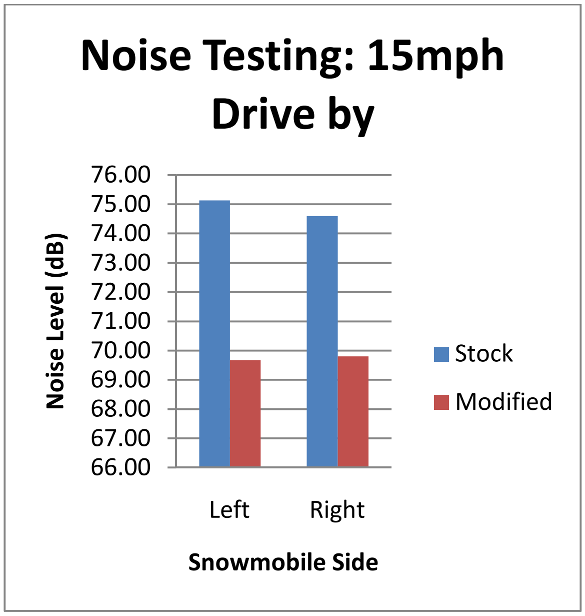


Stock Power Curve via DYNO-mite Software

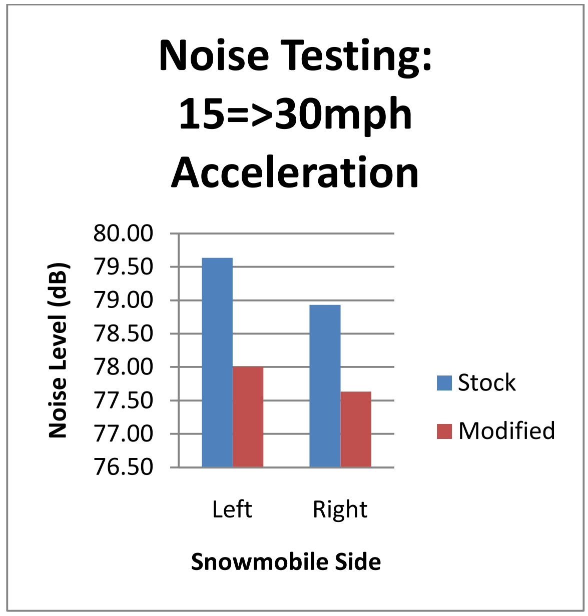


Modified Exhaust Power Curve via DYNO-mite Software

NOISE



Noise Testing: 15 mph Drive by (Constant)



Noise Testing: 15-30 mph Drive by (acceleration)