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Polaris Big Boss noise reduction

Report 2: Component sound source ranking

C. Antelmi
HGC Engineering

Contract Authority: J.L. Giesbrecht, DRDC Suffield, 403-544-4709

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Contract Report

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C. Antelmi

HGC Engineering
Meadowvale Business Centre, Plaza 1, Suite 203
2000 Argentia Road
Mississauga ON L5N 1P7

PWGSC Contract Number: W7702-125412

CSA: J.L. Giesbrecht, DRDC Suffield, 403-544-4709

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ATV NOISE REDUCTION
POLARIS BIG BOSS 800 6X6
Project Reference: EDM-1-34494

REPORT #2

COMPONENT SOUND SOURCE RANKING

Prepared By:
Claudio Antelmi, B.Eng

Reviewed By:
Robert D. Stevens, MASc, PEng

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Abstract

Defence R&D Canada – Suffield is investigating potential avenues of reducing the acoustical signatures of a variety of small all-terrain vehicles (ATVs). Before vehicle modifications are conducted on a test ATV platform, in is necessary to evaluate the sources of noise on the vehicle to prioritize the research effort. This report summarizes an analysis of a Polaris Big Boss 6x6 ATV using sound intensity measurement techniques, providing an estimate of the absolute and relative contributions of each vehicle component to the overall sound level.

Résumé

R et D pour la défense Canada – Suffield mène une étude sur les pistes de solutions éventuelles en matière de réduction des signatures acoustiques d'une vaste gamme de petits véhicules tout terrain (VTT). Avant de procéder à des modifications d'un véhicule sur une plateforme d'essais de VTT, il est nécessaire d'évaluer les sources de bruit sur ce véhicule, afin d'établir les priorités quant aux efforts de recherche. Le présent rapport résume l'analyse d'un VTT Polaris Big Boss 6x6 au moyen de techniques de mesure de l'intensité sonore, en fournissant une estimation des contributions absolues et relatives de chaque composant du véhicule au niveau de bruit global.

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Executive summary

ATV noise reduction for a Polaris Big Boss 6x6: Component sound source ranking

C. Antelmi; DRDC CR 2012-192; Defence R&D Canada – Suffield; November 2012

Introduction or background: Defence R&D Canada – Suffield is investigating potential avenues of reducing the acoustical signatures of a variety of small all-terrain vehicles (ATVs). The project will develop a set of custom modifications that can be applied to ATVs. However, no data on the relative contribution of on-board components to the overall noise signature exists to guide the design of the modifications for noise reduction.

HGC Engineering was contracted to determine the relative and absolute levels of noise produced by the various vehicle components. A Polaris Big Boss 6x6 ATV was tested on a chassis dynamometer using a sound intensity probe to obtain these results.

Results: The results obtained depended on vehicle speed. At lower speeds (24 km/h) the noise produced was dominated by radiated engine noise, exhaust noise, and transmission noise. Internestingly, at higher speeds (48 km/h) the intake air inlet surpassed all of the other noise sources in terms of relative noise contribution.

Significance: These results will guide the design of custom modifications to the ATV platform. Having knowledge of the relative contributions of the noise sources, the designers can now focus on the places where most gains can be made. In this case, the designers will place more emphasis on the intake air inlet than they may have if this information not been available.

Future plans: The custom vehicle modifications will now be made using this information. These measurements will then be repeated on the modified vehicle to determine the overall success of the project as well as the success of each individual modification.

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ATV noise reduction for a Polaris Big Boss 6x6: Component sound source ranking

C. Antelmi; DRDC CR 2012-192; Defence R&D Canada – Suffield; November 2012

Introduction ou contexte: R et D pour la défense Canada – Suffield mène une étude sur les pistes de solutions éventuelles en matière de réduction des signatures acoustiques d'une vaste gamme de petits véhicules tout terrain (VTT). Ce projet permettra l'élaboration d'un ensemble de modifications personnalisées pouvant s'appliquer aux VTT. Il n'existe cependant aucune donnée sur la contribution relative des composants de bord à la signature acoustique globale pour guider la conception de ces modifications visant la réduction du bruit.

On a embauché HGC Engineering pour déterminer les niveaux relatifs et absolus de bruit générés par les différents composants du véhicule. Un VTT Polaris Big Boss 6x6 a fait l'objet d'essais sur un dynamomètre à châssis au moyen d'une sonde de mesure de l'intensité sonore en vue de l'obtention de ces résultats.

Résultats: Les résultats obtenus dépendaient de la vitesse du véhicule. À basse vitesse (24 km/h), le bruit généré était dominé par les émissions de bruit du moteur, de l'échappement et de la transmission. Il est intéressant de constater qu'à des vitesses plus élevées (48 km/h), l'admission d'air a surpassé toutes les autres sources de bruit en termes de contribution relative au bruit.

Importance: Ces résultats guideront la conception des modifications personnalisées à apporter à la plateforme du VTT. Connaissant les contributions relatives des sources de bruit, les concepteurs peuvent maintenant se concentrer sur les points sur lesquels on peut obtenir la majeure partie des progrès. Dans ce cas ci, les concepteurs insisteront davantage sur l'admission d'air qu'ils auraient pu le faire s'ils n'avaient pas disposé de cette information.

Perspectives: Dorénavant, on apportera les modifications personnalisées au véhicule en utilisant cette information. On répétera ensuite ces mesures sur le véhicule modifié, afin de déterminer la réussite globale du projet ainsi que la réussite de chaque modification individuelle.

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1 Introduction

HGC Engineering was awarded a contract by Public Works and Government Services Canada to investigate options to reduce the operating noise level of the 2012 Polaris Big Boss 6X6 all-terrain vehicle (Project Reference: EDM-1-34494). This is the second interim report issued by HGC Engineering for this project and the report summarizes the individual sound sources and their contribution to the overall sound level of the vehicle. Among the major sound sources investigated were the combustion exhaust, the combustion intake air and radiation from the engine and transmission system cases. The resulting analysis provided a ranking of the sources in order of significance which will subsequently be used towards determining the feasibility of various noise reduction measures.

In addition to sound pressure levels discussed extensively in the previous report, this report discusses a quantity referred to as sound power level. Whereas sound pressure level refers to the loudness of sound arriving at a point, sound power level refers to the total rate at which a sound source emits acoustic energy into the surrounding environment. As such, sound power level is a fundamental acoustical quantity, (analogous to a kW rating of a heat source) and it is independent of distance from the source, or the surroundings in which the source is placed. Therefore, when comparing the amount of sound produced by one source versus another, sound power levels are appropriate.

Sound pressure level is a measure of the magnitude of sound pressure oscillations at a point in space, at some specified distance from the sound source (analogous to the temperature at some distance from a heat source). In this regard, sound pressure level depends on the distance from the source at which the measurement is conducted, on the surrounding acoustic environment (e.g., reverberant room versus outdoors), and whether there is any interfering sound from other sources. It is most relevant for assessing the loudness of a sound, its potential audibility, or its severity vis-à-vis operator exposure.

2 Sound evaluation methods

Sound pressure measurement methods were used for the determination of baseline sound levels and will be used as the final performance evaluation criteria. Report #1 presented most data as simple A-weighted results (dBA). Fairly detailed analysis is required for this project and, accordingly, sound intensity measurement methods were adopted for the analysis and results contained within this Report #2. The basic framework and measurement concepts utilized were from ISO Standard 9614-2 , “Determination of Sound Power Levels of Noise Sources Using Sound Intensity - Part 2: Measurement by Scanning”.

Unlike simple measurements of sound pressure with a sound level meter, the sound intensity technique uses a directional probe and sophisticated analyzer to measure both the magnitude and direction of the sound propagating from a source, and can thus accurately isolate the sound emitted by each source from any nearby sources and reject interference from background sound. Typically, the sound intensity probe is used to scan an envelope around a sound radiating source, and the measured sound intensity is then multiplied by the enveloping area to calculate the sound power of the source.

The measurements were conducted using a Brüel & Kjær PULSE model 3560-B-010 Real Time Frequency Analyzer (S/N 2516092) equipped with a Brüel & Kjær model ZH 0632 Sound Intensity Probe and a Brüel & Kjær matched intensity microphone pair

In order for the sound intensity method to be practical for measuring vehicle components while under a realistic load scenario, a chassis dynamometer was used. For this phase of analysis, the appropriate load and speed conditions were determined from the initial baseline pass-by measurements, as presented in Report #1, and approximated on chassis dynamometer at the Automotive Centre of Excellence (ACE) at the University of Ontario Institute of Technology (UOIT). The dynamometer unit was a computer controlled resistance type manufactured by MD Mustang International.

3 Test conditions

As summarized in Report #1, pass-by tests were performed on a paved surface under two scenarios, constant speed at light throttle and also accelerating under full throttle. These two conditions were approximated on the chassis dynamometer. The constant speed condition corresponded to part throttle at 24 km/h and the full throttle condition corresponded to a speed of 48 km/h.

During the controlled conditions on the dynamometer, sound intensity equipment was used to collect sound data from various components and assemblies. Some of this information was reviewed during the test period and the remaining data was later processed for more detailed analysis.

Testing was performed with smooth tread tires for reasons of durability and reduced noise interference. In order to accommodate the dynamometer configuration, the center wheels were removed and the front differential power was not engaged.

Figure 1: ATV with bodywork removed, on chassis dynamometer.

4 Sound source

Data was collected for the following components and systems:

Combustion air intake
Intake box under seat and inlet opening under the main cover in front of the seat.

Exhaust tailpipe outlet
From the OEM muffler tailpipe

Engine RHS and LHS
Sound power radiated from the right hand side and left hand side of the engine system

Transmission RHS and LHS
Sound power radiated from the right hand side or left hand side of the transmission system

Exhaust Pipe Breakout
Sound power radiated from around the single exhaust pipe length between the engine and the muffler.

Transmission Cooling Air Inlet and Outlet
Located under the main cover in front of the seat

Differentials
The Rear Differential transfers power to the rear wheels. The Mid Differential transfers power to middle set of wheels and also to the Rear Differential. The front differential was disengaged for this testing.

Radiator Fan
Switches on and off automatically depending on engine coolant temperature (located at the front of the vehicle)

Sum (All)
The mathematical addition of all the major sound sources that were measured

The mechanical sources were ranked by the magnitude of their sound power levels at the two load conditions defined by half throttle at 24 km/h and full throttle at 48 km/h. The results are presented in Figure 2 and Figure 3 with the sources ranked in order from most to least significant.

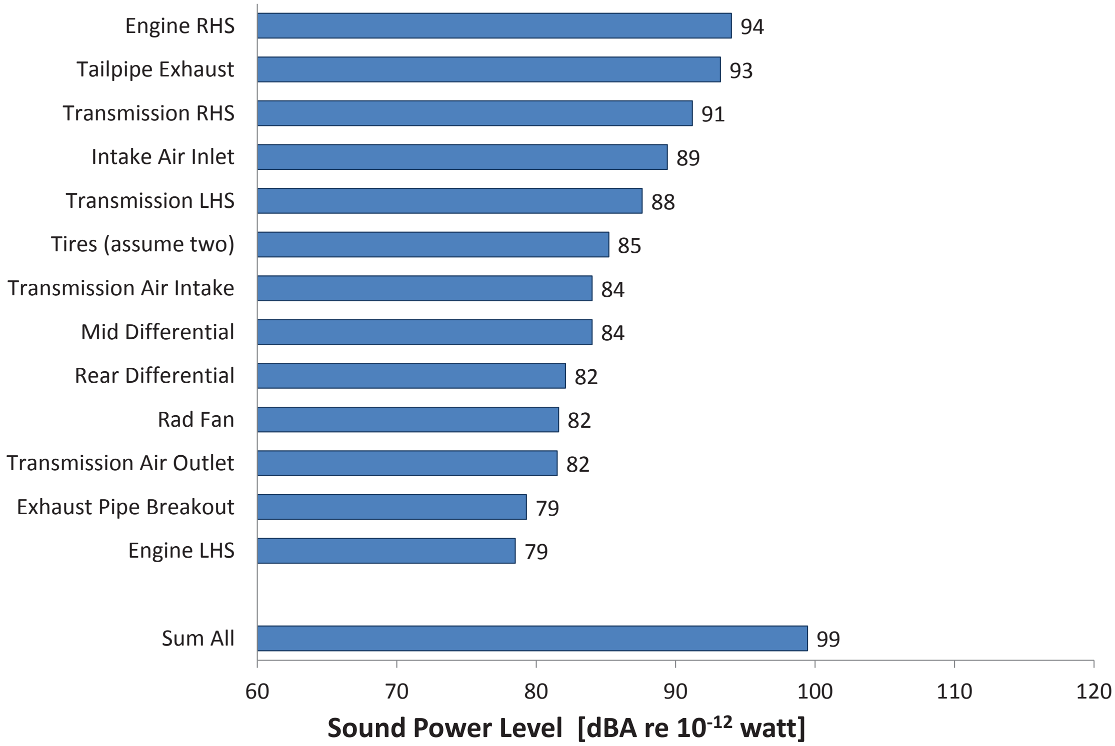

Figure 2: Sound source ranking.
(Part throttle at 24 km/h)

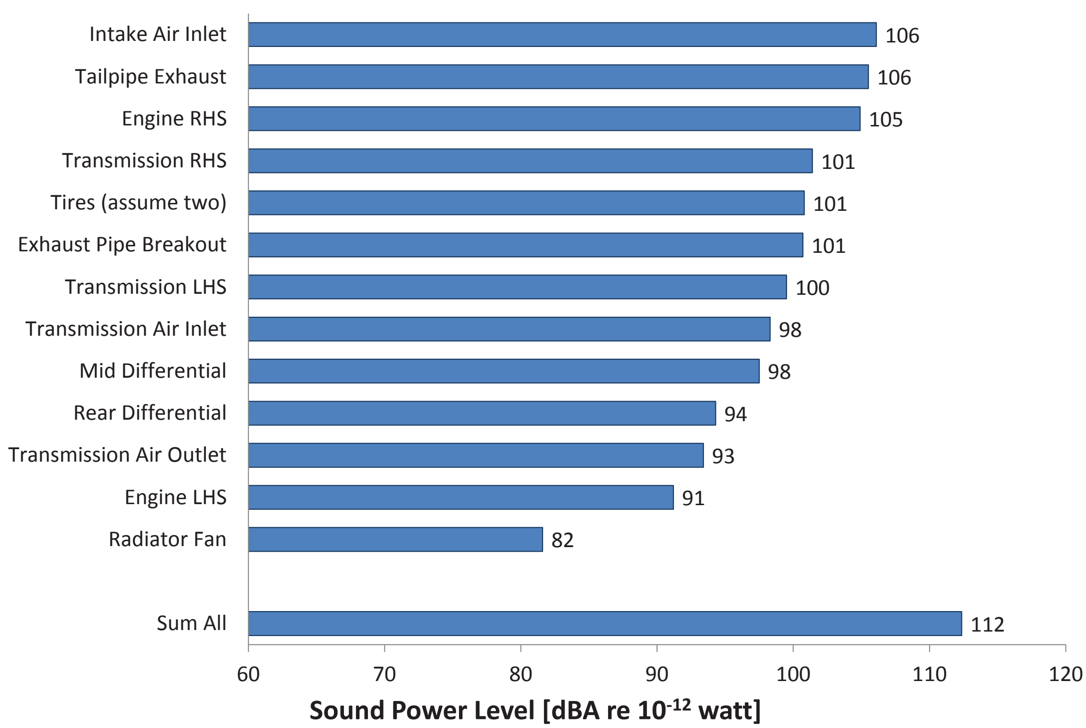

Figure 3: Sound source ranking.
(Full throttle at 48 km/h)

5 Targets for sound attenuation levels

The goal of this project is to achieve as much reduction in sound level as is practical without introducing modifications that will significantly reduce its practical functionality or performance. Ideally, the general noise reduction results would be 10 dBA or better.

When targeting a net sound reduction from a group of unequal sources, the loudest must be treated as a priority and to the greatest degree. Mitigating a lesser source in lieu of a greater source is generally less effective.

The measured sound powers, as summarized in Figure 2 and Figure 3, were analyzed iteratively to determine the minimum number of sources that would need to be treated to achieve a 10 dBA reduction and how much reduction would be needed for each. This iterative process was completed initially using the louder full throttle condition and the results are shown in Table 1.

Table 1: Sound power levels of various sources [dBA re 10^{-12} watt]
(Full throttle 48 km/h)

SOUND SOURCE	BASELINE	NOISE REDUCTION	MITIGATED
Intake Air Inlet *	106	18	88
Tailpipe Exhaust *	106	17	89
Engine RHS *	105	16	89
Transmission RHS *	101	16	85
Tires (assume two)	101		101
Exhaust Pipe Breakout *	101	8	93
Transmission LHS *	100	16	84
Transmission Air Inlet *	98	10	88
Mid Differential	98		98
Rear Differential	94		94
Transmission Air Outlet	93		93
Engine LHS *	91	16	75
Radiator Fan	82		82
Sum (with tire noise omitted)	112	10	102
Sum All (with tire noise)	112	8	104

* Significant sound sources to be investigated initially

The component reductions determined in Table 1 were then applied to part throttle data, as shown in Table 2.

Table 2: Sound power levels of various sources [dBA re 10^{-12} watt]
(Part throttle 24 km/h)

Sound Source	Baseline	Noise Reduction	Mitigated
Engine RHS *	94	16	78
Tailpipe Exhaust *	93	17	76
Transmission RHS *	91	16	75
Intake Air Inlet *	89	18	71
Transmission LHS *	88	16	72
Tires (assume two)	85		85
Transmission Air Inlet *	84	10	74
Mid Differential	84		84
Rear Differential	82		82
Rad Fan	82		82
Transmission Air Outlet	82		82
Exhaust Pipe Breakout *	79	12	67
Engine LHS *	79	16	63
Sum (with tire noise omitted)	99	10	90
Sum All (with tire noise)	99	9	91

* Significant sound sources to be investigated initially

Full throttle operation is considered the worst case scenario for the creation of noise and for engine performance considerations. Under these conditions, the sound from the combustion air intake and exhaust are the dominant sources. A new exhaust silencer design will target a noise reduction of 17 dBA on the chassis dynamometer. An intake silencer will target a noise reduction of 18 dBA. A practically designed integrated enclosure is currently envisioned to reduce the sound from other significant sources such as the engine and transmission casings.

The analysis thus far indicates that tire to surface noise is a non-negligible contributor to the overall sound level when operated on a road surface. Although the goal is for an overall reduction of 10 dBA, it may be impractical to silence tire noise. Consequently, the maximum reductions attainable, when the vehicle is operated on a hard surface, may be 8 dBA for the part throttle test and 9 dBA for the full throttle test (see Table 1 and Table 2).

Various designs will be tested on a chassis dynamometer for appropriate comparisons during the development phase. The final design will be evaluated using the original pass-by testing procedures, as described in Report #1.

6 Summary and upcoming phases

For this phase of the project, sound intensity measurement methods were used to isolate and identify significant sound sources for the vehicle under various conditions. This testing was performed in a controlled environment using a chassis dynamometer.

A new exhaust system will be designed considering a targeted source noise reduction of 17 dBA, as measured in the near field, using sound intensity methods on a chassis dynamometer. The next report will present results of the new design which may be an iterative process and could be revised before the end of the project.

Targets for the major contributors have been assigned and the designs will progress for silencing the combustion air intake, transmission cooling air system and engine casing radiation. More detailed analysis of these systems will be presented in subsequent reports.

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