



Towards a reduction of noise emission of powered two-wheels - Part 2.

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ABSTRACT

Transportation in urban areas is often synonymous of traffic congestion. In the last decade, this situation led users to give up passenger cars and incited them to adopt powered two-wheelers (PTW), better adapted to the traffic hazards. In the frame of the French research project Ascoot (Acoustique des scooters et des motorcycles), this paper focuses on the acoustic optimization performed on two scooters, including diagnosis and computation methodologies, leading to technical solutions implemented on 2 prototypes. The acoustic sources were located and quantified by acoustic imaging on roller benches, and the vibration behavior was characterized by means of experimental modal analysis (EMA) and measurement in operation. A simulation model was build for solutions design: excitation forces were derived from the measured combustion pressure and from a cinematic model of the engine moving parts, whereas structural dynamic response was computed by a Finite Element Model (correlated with EMA). An optimization of muffler design was also performed using transfer matrix models. The implementation of the noise reduction solutions on both prototypes is in progress; a minimum of 3dB noise abatement is expected.

Keywords: Noise emission, powered two-wheels, Road traffic noise I-INCE Classification of Subjects
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1. INTRODUCTION

In a context of strongest traffic congestion in urban areas, using powered two-wheelers, particularly scooters, can be considered as an acceptable solution to avoid jammed traffic situations. However their noise emission must be controlled. French research project Ascoot (Acoustique des scooters et des motorcycles), aims at designing acoustic solutions for two scooters, Diagnosis and computation methodologies are briefly presented.

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2. DIAGNOSIS

2.1 Acoustic Holography

An acoustic measurement campaign has been carried out on a roller bench, including 2 Peugeot scooters and 2 competitors. Predominant acoustic sources could be rapidly detected using a HDCam irregular antenna fitted with 36 microphones, and Irregular Nearfield Acoustical Holography treatment [1].

Figure 1 presents holograms on both sides of Peugeot 2 strokes scooter. The noise emission is identified:

- On the left side: either the transmission casing or the engine radiating through a chink
- The cooling grid on the right side.

The frequency content of the noise radiated by the cooling grid includes both the turbine blades and the engine orders. Diagnosis was confirmed and refined during a second vibro-acoustic measurement campaign.

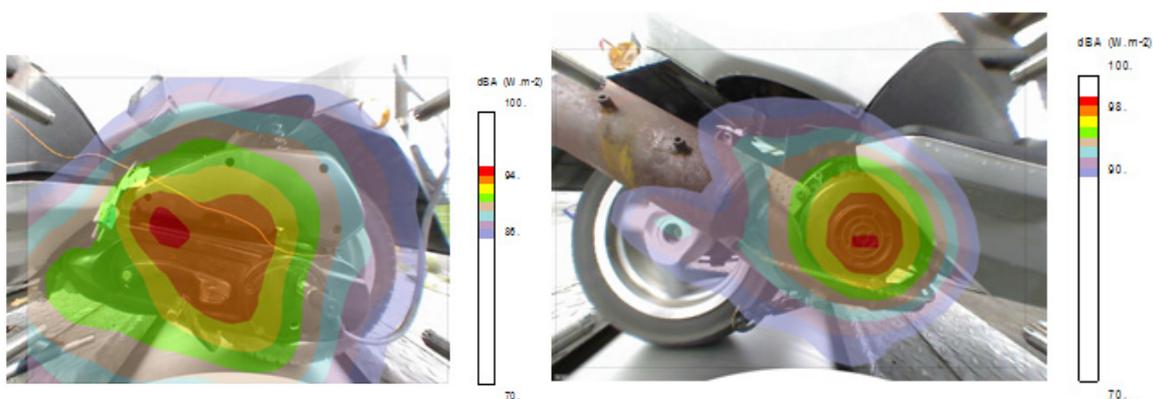


Figure 1 – Acoustic holography of 2 strokes 50cc scooter at 30km/h, full load.

Left/right side. Global A level

Holograms on 125cc 4 strokes scooter indicate major noise radiation from :

- The transmission casing on the left side, close to the gearbox
- Both wheel-roll contact and engine casing on the right side
- Radiation of the exhaust skin, and also the outlet (not visible here), are also suspected.

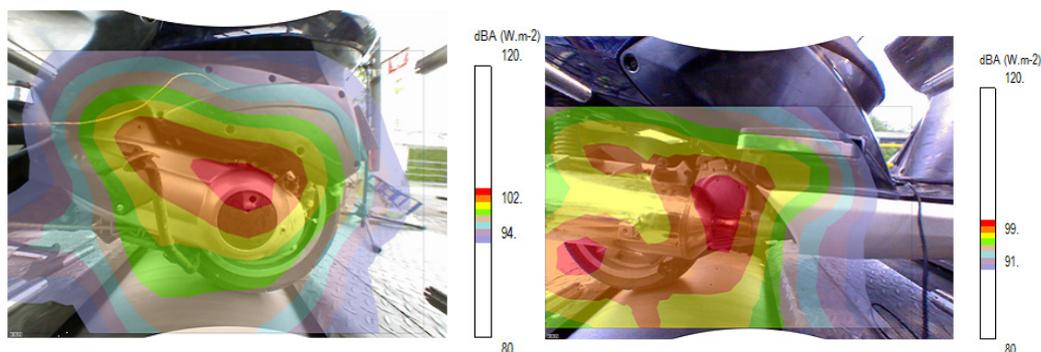


Figure 2– Acoustic holography of a 4 strokes 125cc scooter at 30km/h, full load.

Left / right side. Global A level

2.2 Vibro-acoustic diagnostic

Acoustic holography helped focusing on predominant sources. But more insight on vibroacoustic phenomena is needed to design noise reduction solutions.

2.2.1 Operational measurements

Acceleration on radiating sources was measured on a roller bench.

On the 2 strokes 50cc scooter, the cooling fins are strongly vibrating, and happened to be the predominant source, mostly responsible for the noise radiated through the cooling grid (Figure 3).

Its low damped modal behavior is confirmed by vibro-acoustic transfer function measured with a chock hammer and a response microphone in a semi-anechoic chamber (Figure 4). A stiffened cylinder casing has been tested, resulting in slightly higher resonance frequencies (pink curve), but still high response due to low damping (1%). Dampers and shields appeared to be more efficient solutions.

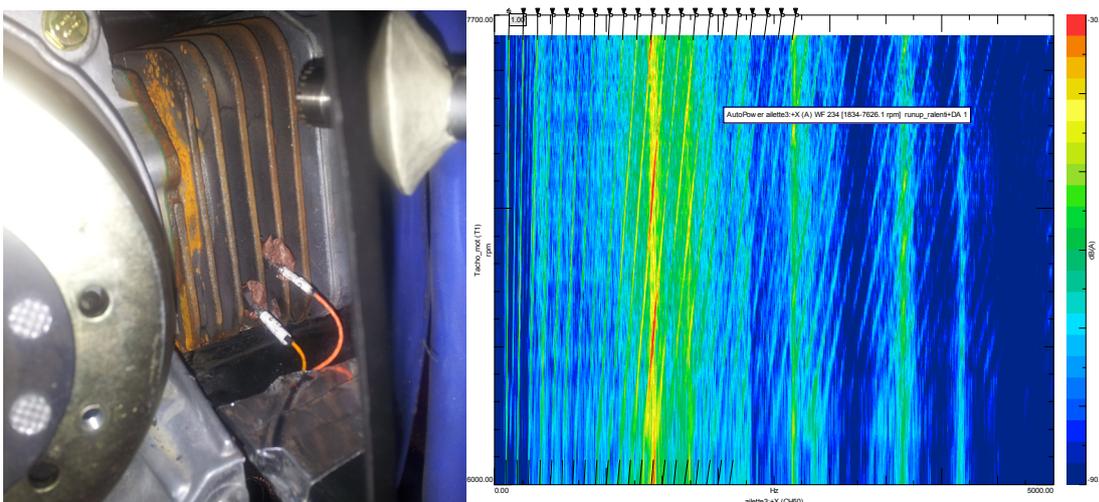


Figure 3 Operational vibration on the cooling fins

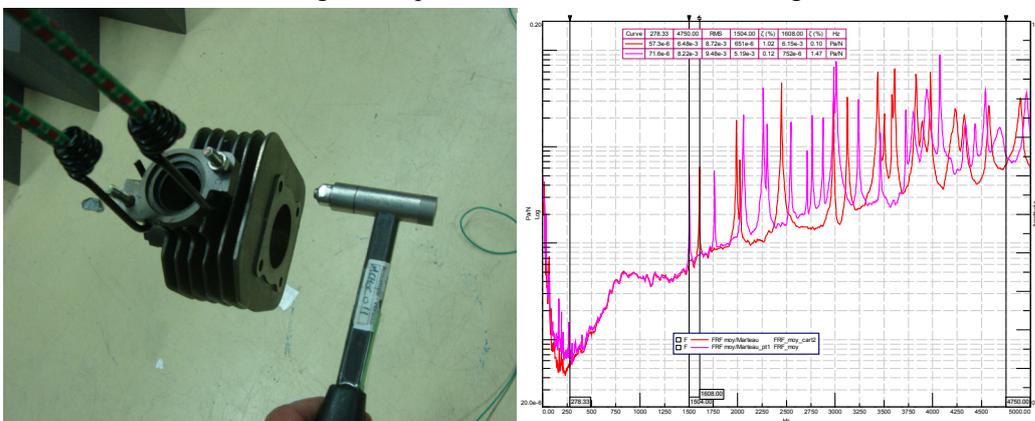


Figure 4 Vibro-acoustic transfer function of the cylinder casing

No specific high vibration level was found on the top of the transmission casing, nor on the intake filter, which indicates that the noise source might originate from the upper part of the engine.

Concerning the 125cc 4 strokes scooter, an additional pressure sensor was set in the combustion chamber and analyzed in angular domain. The idea was to check the influence of the combustion pressure on vibration and noise, to derive forces transmitted via the bearing of the crankshaft, and to test several combustion parameters.

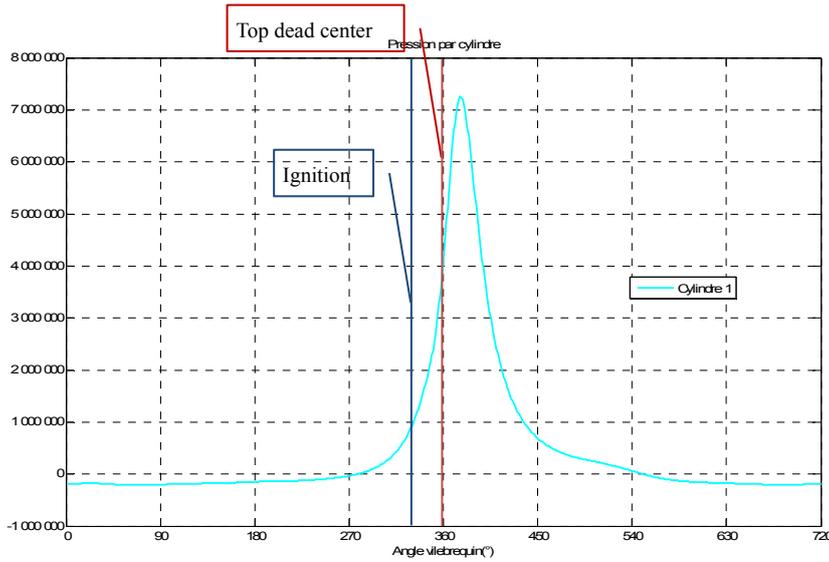


Figure 5 Cylinder pressure (Pa) versus crankshaft angle

2.3 Loads on the engine block

A program has been developed to derive force tensor applied by the crankshaft on the engine block, based on the inertial characteristics of the mobile parts, the rotation speed and the measured combustion pressure. The theory can be found in the literature [2].

As expected for a mono-cylinder, the vertical force, essentially due to translation inertia, dominates over the transverse force, due to rotation inertia.

The roll torque is due to both combustion and rotation inertia, which slightly compensate each other.

Once expressed on bearings and cylinder liner and after a Fourier transform (Figure 8), the forces can be combined with either measured or computed transfer functions to compute their contributions to the vibration of the casing. Combustion forces are distributed over a wide range of harmonics, whereas vertical forces are concentrated on the first even orders.

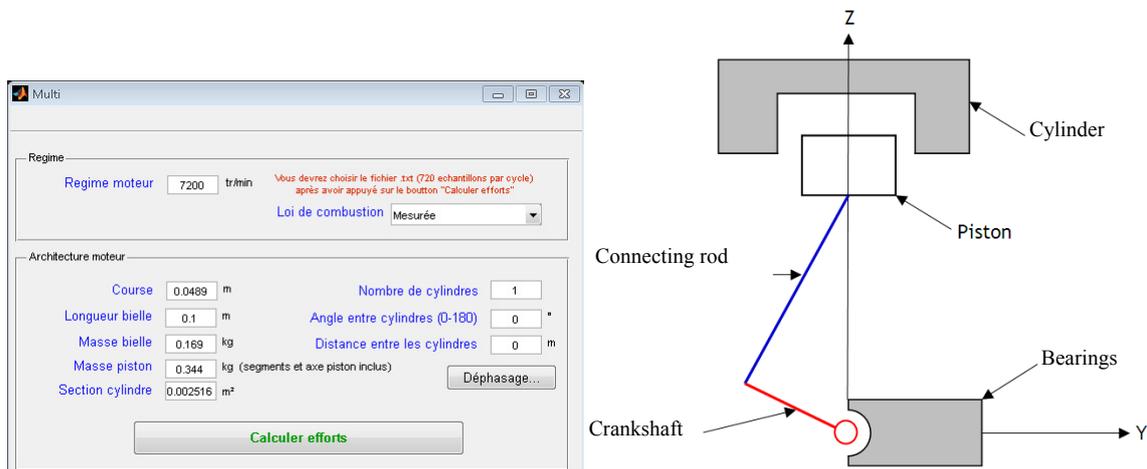


Figure 6 – Interface of Vibratéc program for the derivation of excitation tensor

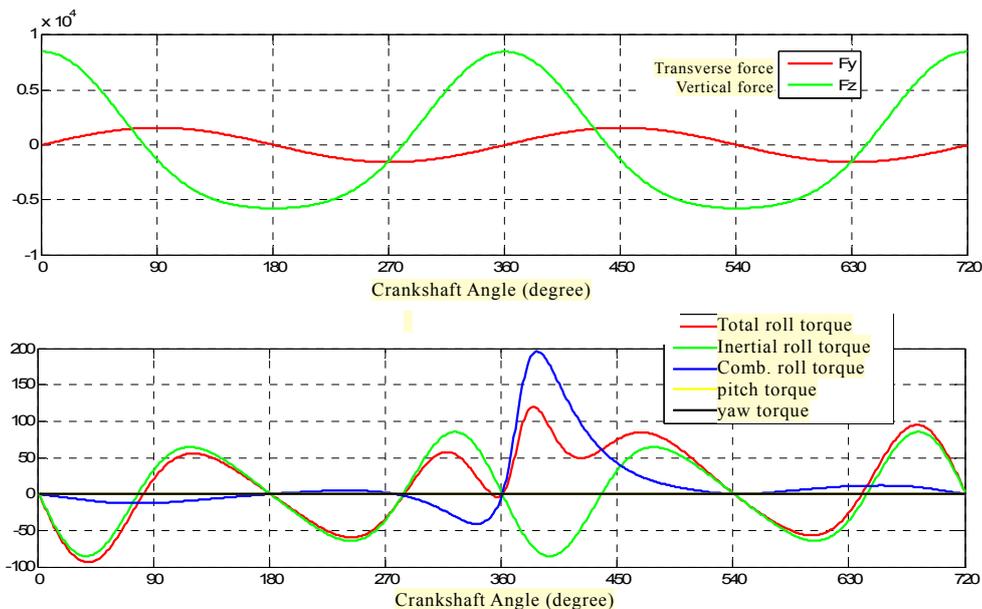


Figure 7 Computed Forces and torques versus crankshaft angle

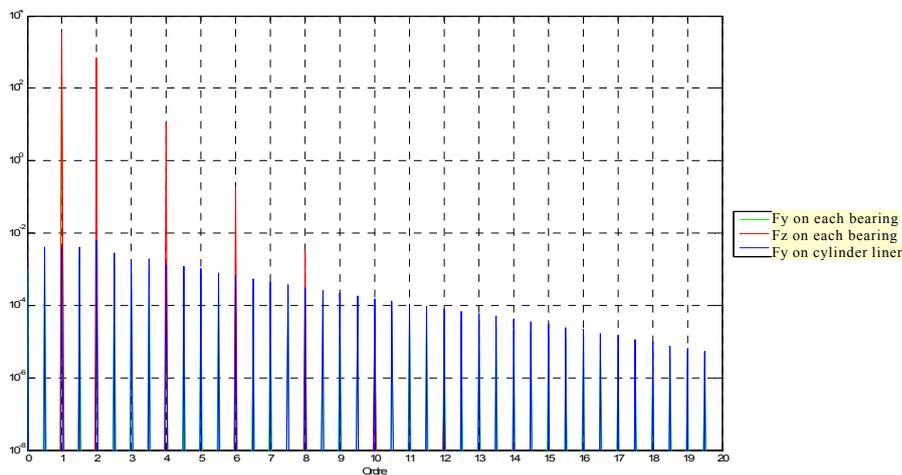


Figure 8 – Order spectrum of forces on crankshaft bearing and on cylinder liner

2.3.1 Experimental and numerical modal analysis

An experimental modal analysis was performed on the engine and transmission casing. The experimental setup is shown on Figure 9.

Vibration transfer functions are compared to finite element results on Figure 10 and Figure 11. The main features (resonance frequencies and order of magnitudes) are captured, although modeling contact stiffness and damping in casings assembly is rather tricky.



Figure 9 – Experimental modal analysis of the engine and casings of 125cc 4 strokes scooter

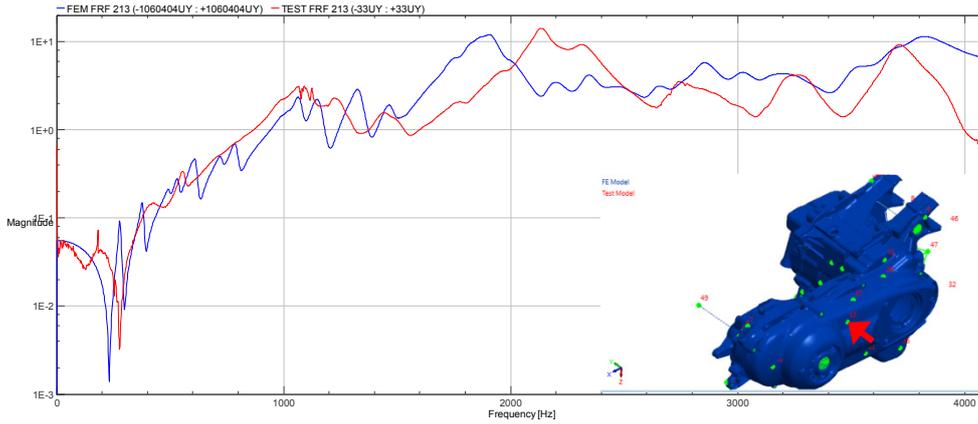


Figure 10 - Local response on transmission casing

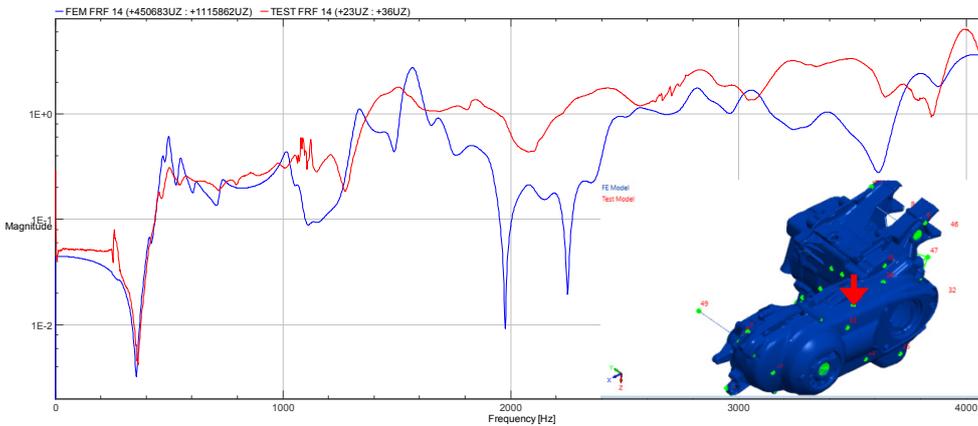


Figure 11 – Transfer function from crankshaft bearing to transmission casing

2.4 Exhaust muffler

The exhaust noise is usually a major noise source for scooters.

The original muffler of 125cc 4 strokes scooter was measured on a specific test rig, allowing measurement with flow. It happened to be quite efficient in terms of transmission loss, except weaknesses at 1200 Hz and 2400 Hz.

Optimizations were modeled, using 1D transfer matrix and 3D finite element models, but the prototypes were rather disappointing.

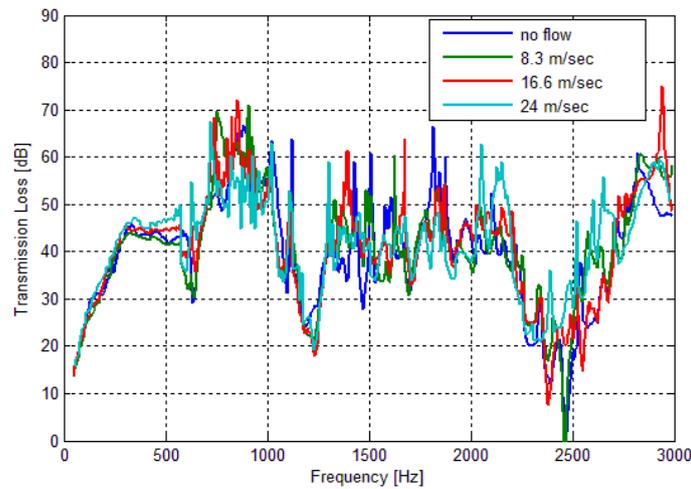


Figure 12 Exhaust muffler measured transmission loss with and without flow.

3. NOISE REDUCTION SOLUTIONS

3.1 50cc 2-strokes scooter

Based on Vibratec experimental diagnosis and Peugeot Scooter experience, the following parts were optimized:

- A aluminum cylinder block was prototyped (replacing cast iron)
- The cylinder cooling fins were fitted with dampers
- An acoustically optimized cooling fan was adapted
- A double-skin engine cover was designed and prototyped.

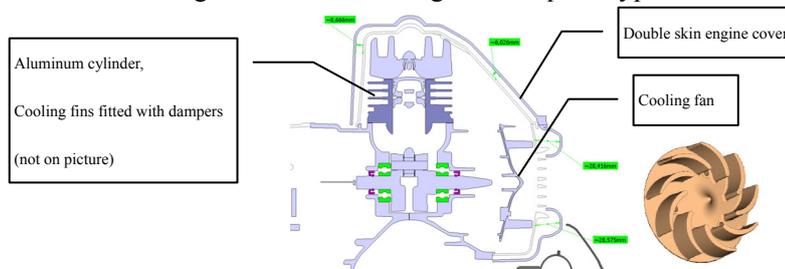


Figure 13 – Main solutions developed for the 50cc 2 strokes scooter

3.2 125cc 4-strokes engine

The following actions were carried out:

- 3 versions of prototype mufflers were built.
- Prototypes of uncoupled covers were designed for the transmission casing and the right engine casing.
- Combustion parameters were tuned, particularly the ignition time.

4. PASS-BY RESULTS

Both prototyped vehicles and original vehicles were tested on a homologated acoustic track, in the condition of the new pass-by noise regulation. The following acoustic gains were observed.

On 50cc 2-strokes prototype, an gain of 2 dBA was observed during full load acceleration on the left homologation microphone and a gain of 2.5 dBA on the right side. The exhaust nozzle seems to be responsible for remaining noise.

On 125cc 4-strokes prototype, no gain was found with the shields and the new muffler prototypes. The new designs of muffler were disappointing, and exhaust noise is covering the gains obtained with the shields.

Acoustic pass-by noise cartography with “de-dopplerisation pre-process” (Figure 14) clearly indicates the muffler nozzle and its reflection on the ground as the predominant source.

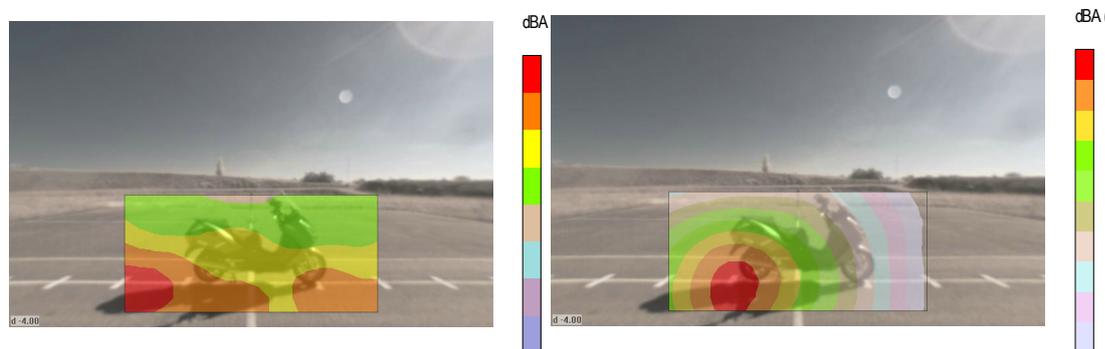


Figure 14 – Pass-by-noise cartography – [315Hz-2000Hz] – 125cc prototype

Left : standard beamforming – Right : Beamforming with “de-dopplerized” signal

Postponing the ignition time by 2 degrees, 5 degrees and 10 degrees, provided gains of 0.2 dB, 2.1 dB and 4.1 dB respectively. Measurement showed that the ignition time has a great effect on the amplitude of the combustion pressure, which influences both vibro-acoustic response of the engine

block, and the acoustic source in the exhaust muffler.

However this solution also affects the performance of the scooter in terms of acceleration and maximal speed and especially, it highly raises the fuel consumption. Thus this solution is not really acceptable though it points out that there are probably linked solutions.

This is why Peugeot scooter is also working on alternative solutions, like decreasing the compression rate via geometrical changes, to reduce the maximal combustion pressure while keeping good mobility performances, which is a strong identity of the brand.

5. CONCLUSIONS

A wide range of experimental and numerical techniques has been deployed to diagnose and optimize the noise emission from scooters.

Several solutions have been successfully tested in pass-by-noise conditions.

However further optimization of the mufflers and combustion tuning are still needed to end-up with really low-noise scooters.

ACKNOWLEDGEMENTS

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